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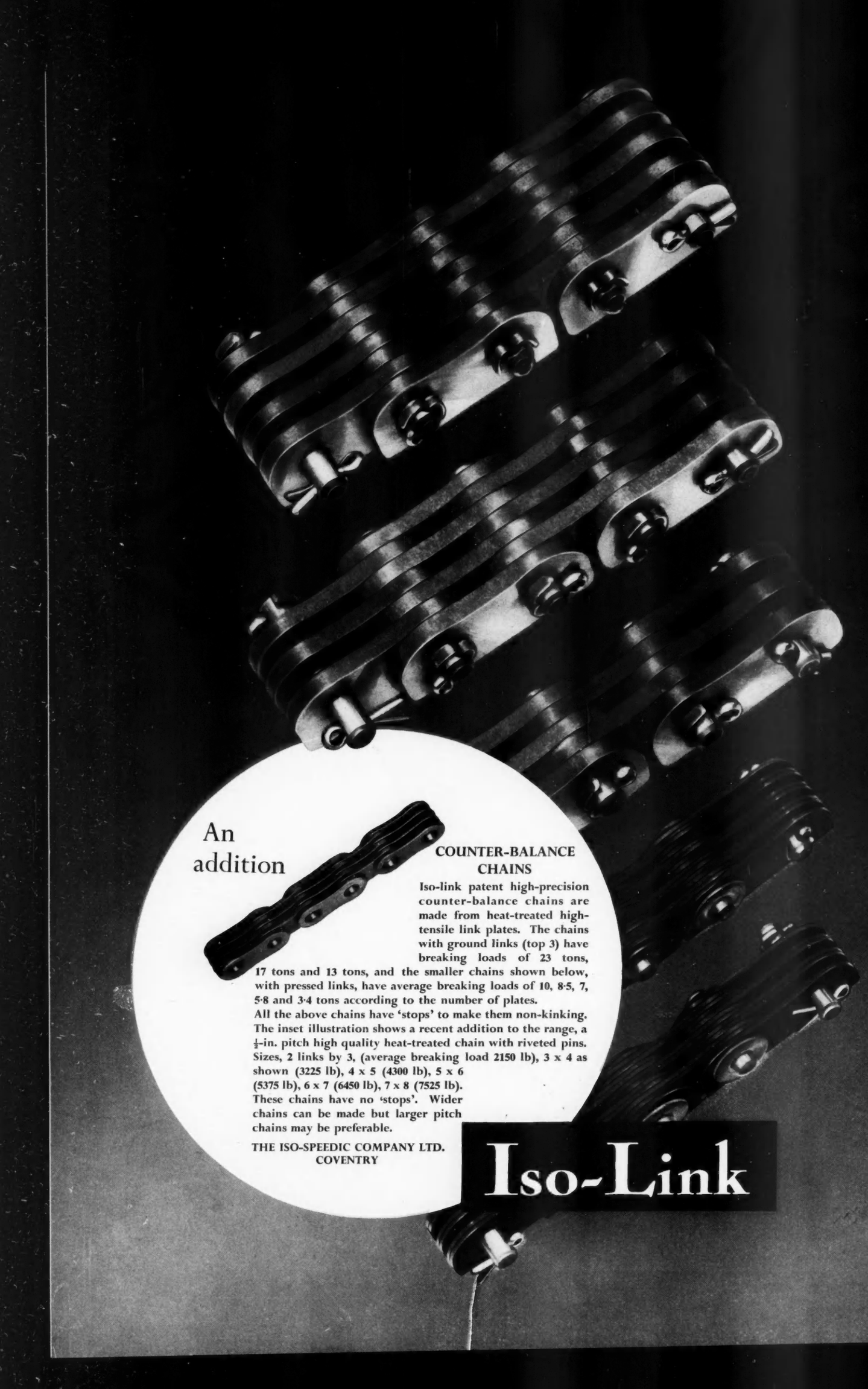
ETCHING GRATICULES



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ENGINEERING

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Vol. 182 No. 4713 JULY 6, 1956

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SKILLS QUICKLY ACQUIRED

You have heard, of course, of the modern method of training machine operators. It saves time and money. It economises in material and raises the quality of work. It reduces labour turnover, and it can be applied as well to experienced workers transferred to new machines as to raw recruits.

The method is analytical and is altogether different from the haphazard acquisition of skill during an apprenticeship of the traditional kind. It consists of seven stages. First, the knowledge and skills involved in the job—the "knowledge content" and the "skills content"—are determined. Second, the skills of experienced workers are analysed—the use of the senses as well as the movements involved being studied. Third, if the analysis shows that there are special difficulties in the job, preliminary training exercises and devices are designed. Fourth, the job is divided into parts suitable for training purposes, particular attention being given to those parts which require greater use of the senses or of making decisions. Fifth, in a training shop separate from the production shop, the trainees practise the preliminary exercises, then practise the parts of the job, and when they are as proficient in each part of the job as an experienced worker, they perform the parts in sequence. Sixth, when the trainee can perform one cycle of the job at experienced workers' standard he graduates to two, four, eight cycles, and so on; then he continues for an hour—two, four, eight hours. At each stage a longer period is not attempted until the target has been achieved on the previous, shorter period. Finally, with the aid of a quality specification and a fault specification, training on quality and faults is given. By this method, "experience not otherwise gained after perhaps years in the shop may be inculcated in a series of brief lessons." That is the opinion of Mr. W. Douglas Seymour, the author of a valuable article on the subject which appears in this issue.

His opinion is amply supported by the experience he quotes of analytical training at the works of three well-known engineering firms—Joseph Lucas, Limited; Guest, Keen and Nettlefolds (Midlands), Limited; and the General Electric Company, Limited. At the Lucas works, nearly 1,000 trainees pass through the department annually. At the G.K.N. establishment the scrap work produced is reported to have diminished markedly since the scheme was introduced. Analytical training has been found to be particularly effective in the case of older workers who are required to operate new machines, and the workers themselves have appreciated being better able to understand their job. On cold-heading machines, men now reach a degree of skill in four to six months that previously required four years in the shops. In the G.E.C. works, operators are trained in three weeks instead of twelve, or two instead of five, depending on the type of work. Overall savings due to analytical training are considerably greater than the cost of the scheme. And no doubt the production departments are delighted to be freed of training worries.

Mr. Seymour proposes that the engineering industry, like the cotton industry, might develop the analyses and training programmes for standard operations and then make arrangements to teach training officers to use them. Trade associations or research associations which are in close touch with certain branches of engineering would be the obvious bodies to give a lead. It would, too, be a strong selling point for, say, a machine-tool maker to be able to supply, with his machines, the analyses and training programmes that could be used straight away by the customer. The initial analytical work would thus be done once and for all.

Effective training of operators is of vital importance when a new or branch factory is opened. In such a case recently the British Thomson-Houston Company established a nucleus of operators by bringing a number of women from their home town in Scotland, where the factory was being started, to an existing factory in England, and trained them for work of a kind which had not been done in the Scottish town before. The analytical method described by Mr. Seymour should throw light on the nature of skills for which women and men are particularly suitable. There is also undoubtedly a difference between the skills appropriate to young and old workers. Certainly there are differences between the natural aptitudes of different workers when they are only given the unorganised training which has sufficed in the past. Analytical training, however, should go a long way towards ensuring that the less apt develop on the right lines, so that they do not reach a limit which is below the best performance of which they are capable.

The more one examines Mr. Seymour's review of the subject the more apparent it is that analytical training is but part of a much wider conception of men, machines and production. It ties in with the new science of cybernetics—the design of machines in relation to human physiology and psychology—and thereby it raises other questions which will inevitably be probed in the future. If, for example, operators are trained away from the production shop, and with the aid of

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special training devices, it may be that the design of the normal production machine could be modified with advantage; though the design would no longer be simple for the operator who had had no special training, it would give exceptional performance in the hands of one who had. There is plenty of such research to be done. For the immediate future the method of analytical training has been developed, and found beneficial.

* * *

Plain Words

The sudden dismissal by the British Motor Corporation of 6,000 employees has shocked the whole country. Conservative and Labour M.P.s alike have tabled motions in the House of Commons deploring the company's action. The belief that the move, in its manner and timing, had political motives is widely held. Coming, as it did, at the time of the strongest union opposition to the dismissals by the Standard Motor Company it dealt a hammer blow to the unions confidence. Nothing could have given more spectacular support to the engineering employers' federation in their warning last week that any claims for further increases in pay would be rejected out of hand.

B.M.C.'s chairman, Sir Leonard Lord, is ill and cannot face his critics for several weeks. His action has been described by the Minister of Labour as " profoundly disturbing," not because he dismissed the men but because he did so without consulting unions or the Government. Mr. McLeod quite rightly complains that his department are not being given a chance to do anything for the dismissed men, at a time when they have to find alternative employment for 2,500 Standard redundant employees. Jobs are available in the area, more than 6,000 of the vacancies in Birmingham itself and over 27,000 in the region as a whole. But transfers take time and can lead to serious hardship. The only valid excuse is that the company were faced with a sudden emergency. This, however, is not the case. There has been under-employment in several of the B.M.C. factories, and particularly at Longbridge, for about six months.

Not all companies in the motor industry take the view that it is a good thing to recruit men to get higher output, at any rate until all overtime capacity has been absorbed and the possibility of introducing more productive machinery thoroughly explored. Fluctuations in demand —which are part and parcel of motor vehicle manufacturing—can thus be absorbed without declaring any redundancy or recruiting additional labour. About two years ago B.M.C. announced that they would raise output to 2,500 vehicles a day by March, 1956. This they did, and swelled their labour force accordingly. Earlier this year they found they could not hold output, mainly because Austin cars were not selling up to expectations either at home or overseas. Their share of the output of the " Big Six " fell slightly, and when news of the Australian cuts reached the company it became clear that the labour force must be reduced. The redundancy at Standard helped to make the decision easier, since it released good labour in the area (Austin account for over half the total dismissals) which could be picked up when required. It can only be assumed that the suddenness of the announcement was designed to avoid union pressure to introduce more short-time.

B.M.C. have acted foolishly—this much is now plain—and in so doing have lowered the confidence of the country, and of customers overseas, in the ability of the British motor industry to expand successfully. Others are better placed: the fact that Ford Motor Company shares yield 4·6 per cent. whereas those of B.M.C. yield 9·6 per cent. is evidence of the view taken by the City on the ability of a successful company to expand its share of the market.

TRAINING OPERATORS FOR THE ENGINEERING INDUSTRY

*By W. Douglas Seymour**

The increase in industrial production in the past 10 years has probably been nowhere more marked than in the engineering industry. Here, expansion has been attained by more mechanisation, better tools and machinery, less wasteful methods of work and better organisation, and by these means operator productivity has been greatly increased. But production is still dependent on the worker and, even in the highly mechanised industry of to-day, the key to higher productivity still often lies in the manual skills of the individual workers. Little, if anything, can be produced without some intervention of the human operator, and the greater the power and mechanical resources behind him, the greater the difference his skills and abilities can make to output.

In these years of overfull employment, the skills of the so-called unskilled or semi-skilled workers have—in spite of mechanisation—become increasingly important, and greater attention is being devoted to operator training to-day than probably at any time since the Industrial Revolution. Labour shortage, high labour turnover, higher standards of productivity, demands for better quality and greater diversity, and more costly plant—all these emphasise the necessity for better training, so that such workers as are available can be enabled to produce adequately, satisfactorily and remuneratively in the shortest possible time, and with sufficient flexibility to be able to cope with modern technological change.

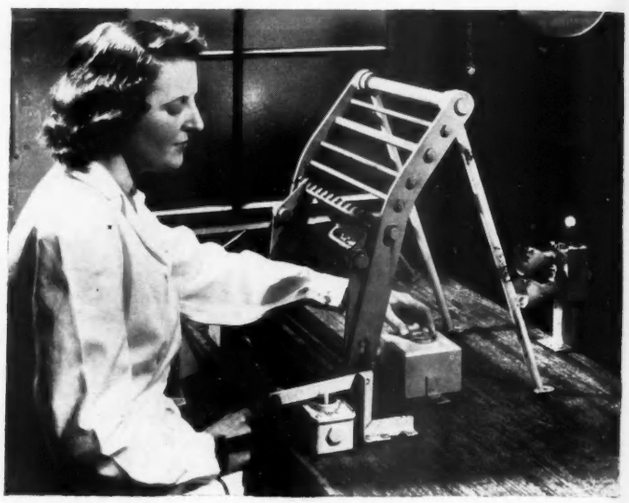

Fig. 1 At Joseph Lucas Limited, power-press operators learn the rhythm of the required movements on a training device.

Probably because we in the United Kingdom have felt the effects of full employment more than other industrial nations, closer attention has been devoted to operator training here than elsewhere. Even during the last war, the acceptance of training was more widespread here than in America, and its influence has been more lasting. Also during the war period, a new and more advanced form of operator training was initiated in this country, largely as a result of the dire needs of industry at the time. This form of training, known variously as " analytical" or " specialised operator training," has developed rapidly in the post-war years; on the one hand there has been a great increase in the number of industries which have adopted it, and on the other there has been a greater understanding of industrial skills and their acquisition.

Latterly, this understanding has been reinforced by the results of researches on manual skills which are proceeding in various universities and institutions. At Cambridge in the Medical Research Council, Applied Psychology Unit and Psychology Laboratory the study of skills—primarily those involved in Service activities—has provided invaluable help in skills analysis. At Birmingham University, in the Department of Engineering Production, a project devoted exclusively to the study of the nature and acquisition of industrial skills has been progressing for more than four years. More recently this and other projects under the M.R.C.-D.S.I.R. Joint Committee on Individual Efficiency in Industry, under the chairmanship of Sir Frederic Bartlett, have, with the assistance of United States Counterpart Aid Funds, devoted attention to a variety of detailed aspects of industrial skills and operator training.

Thus, as a result of factory experience and laboratory research, there now exist in this country techniques of specialised analytical operator training. Such training starts with two fundamental axioms:—

(1) Training must be considered to extend until the trainee attains the standard of output and quality of an experienced worker; and (2) unless training is based on the analysis and understanding of the skills of the experienced worker, attempts to create those skills in new recruits will be no better than haphazard.

STEPS IN TRAINING

The training procedures, then, involve the following steps. (*a*) The knowledge content and skills content of the job are first determined. (*b*) An analysis is made of the skills of the experienced workers, and as much attention given to the use of the senses as to the movements involved. Target standards, equivalent to experienced workers' standard of output and quality, are determined for each part of the job. (*c*) Where the analysis indicates that there are special difficulties, preliminary training exercises and devices are designed. (*d*) After scrutiny of the analysis, the task is divided into suitable parts for training, special emphasis being given to sections which involve greater use of the senses or of making decisions. (*e*) Trainees, normally in pairs and in a training centre separate from, but adjacent to, the shop, practise the preliminary exercises, then practise the sections of the job, and proceed to perform the parts together only when each has been mastered to experienced workers' standard of output and quality. (*f*) When one cycle of the operation has been performed at experienced workers' standard, trainees attempt two, four, eight cycles and so on; then an hour's run, two-hour, four-hour, and eight-hour runs, passing to a longer period only when targets have been achieved on the preceding shorter period. (*g*) A quality specification is drawn up, together with a fault analysis specifying and illustrating each type of fault. Systematic training on faults and quality is given so that experi-

* University Research Fellow, Dept. of Engineering Production, University of Birmingham.

ence not otherwise gained after perhaps years in the shop may be inculcated in a series of brief lessons.

By the use of these techniques in a wide range of industries, including mechanical and electrical engineering, screw-making, pottery, hosiery manufacture, garment making, knitting, weaving, spinning and footwear manufacture, it has been found possible to reduce the time required for new recruits to attain the experienced workers' level of performance to about one half or one-third of that previously required. A reduction in training time of this order, coupled with the higher productivity achieved, leads to economies which in general far outweigh the cost of setting up training schemes. The savings in direct labour cost may vary from a few pounds to nearly £50 per trainee, and the economies in increased overhead recovery may vary from £20 to over £100 per trainee. In certain cases, better utilisation of material and improved quality outweigh all other financial savings. The installation of improved training, in instances where records were available, has been associated with a reduction in labour turnover and an increase in the " yield " of trained workers.

The application of these techniques in the engineering industry can be exemplified from the experiences of three companies—Joseph Lucas Limited, Guest, Keen and Nettlefolds (Midlands), Limited, and the General Electric Company, Limited, at Witton, Birmingham—who have kindly permitted the following details of their training schemes to be published. The products of these three firms involve the use of a wide range of manufacturing operations representative of the engineering industry as a whole; it is not possible to describe all the special training courses they employ, but the outstanding features of each firm's training are reported.

TRAINING AT JOSEPH LUCAS, LIMITED

This firm introduced special training methods into its existing operator training centre during the latter years of the war, since when various modifications have been made to keep the courses up-to-date.

It will suffice here to deal specifically with the training of female operators on the " bread and butter " engineering machine tools—power presses, capstan, milling and drilling machines.

Power Press.—Originally, after instruction partly in a training centre and partly in the shop, operators were able to attain average experienced workers' standard after 11 weeks. Subsequently by specialised training this was appreciably reduced, and the course now extends over two to three weeks. Trainees normally do at least one day's run at experienced workers' standard before being transferred to the shop, where they spend a " try-out " period before being finally handed over to shop supervision.

Trainees, selected by interview and test procedures, are, after an explanation of the job, taught the various rhythm patterns involved in press operation. The teaching of these rhythms is based on the analysis of experienced operators, and is achieved initially by practice on a training device (Fig. 1). This consists of a " mock-up " of the job, on which trainees practise the exact movements required, the completion of which is shown by indicator lights. Targets at experienced workers' standard are set for short and for gradually longer periods of work. Not only does the use of the device aim at teaching the correct movement, but also at inculcating safe working habits—if the hands when working the machine are always by habit in the right place, no accident can occur.

Trainees then do short practice runs on the machine, after its working parts, safety requirements, etc., have been explained to them. As soon as they attain their " target," the working periods are progressively lengthened. Talks on the company's products, standards of quality, etc., are interspersed in the programme in addition to those on factory matters such as method of payment, works rules, etc.

Milling and Drilling.—Factory requirements frequently call for general machinists, and girls trained on drilling are usually taught milling, tapping and bench lathe work also The course is similar in plan to that for press work—introduction, practice on devices and exercises, short runs on machines, gradually extended, interspersed with talks on the job and allied matters.

During the past 10 years, over 1,000 women have been given this training. Many were imported labour, and the turnover is inevitably rather high on this as on the other operations described.

Capstan.—This course takes rather longer—usually four weeks—and aims at training operators on a variety of types of work found in the factory. The factory work has been analysed into basic elements—for here, as usually on capstan work, the infinite number of possible jobs can be categorised into certain types of component, of work holding, of cross-slide tooling, of turret-tooling, etc.

The correct sequence of operations is taught by a special device which consists of a capstan wired with switches, relays, etc, so that if the sequence is followed, signal lights give the necessary indication. Failure to follow the sequence is shown by the absence of a signal at the particular stage.

Attention has been devoted to teaching correct tool approach and tool pressures. Analysis shows that the development of kinaesthetic sensitivity to judge the appropriate pressure on star-wheel and cross-slide handle for cutting metals of different hardness is important. Although some indication is available from the swarf, correct pressure is difficult to acquire and impossible to describe. Earlier attempts at designing a device to teach this were not wholly satisfactory, and a new method is being investigated, based on apparatus which has proved satisfactory in the laboratory.

The knowledge content of the capstan courses is greater than that of the other courses, and more time is devoted to talks on the machine and its tools. In addition, the Synchrophone (a visual and aural aid) is used for illustrated " lectures " on the care of cutters, safety, and methods of work.

The courses outlined cover only three of the numerous operations taught in the operator-training department, which is a central department serving two of the largest factories. As nearly 1,000 trainees pass through each year, valuable experience on administration has been gained. The transfer of trainees to the shops is supervised by a " follow-up " instructress, who makes a link between training and production

TABLE I.—*Fault Analysis, Nicking and Turning, Woodscrews and Metal Threads*

Fault	Nick too deep	Nick too shallow
Appearance	Depth of nick greater than gauge indicates.	Depth of nick less than gauge indicates.
Cause	Saw set too far into head.	(*a*) Saw not set far enough into head. (*b*) Too much metal being taken from surface of head.
Effect	Head made weak—scrap.	Depth of nick not sufficient for correct use of screwdriver—scrap.
Responsibility	Operator.	(*a*) Operator. (*b*) Operator.
Action	Reset saw to cut less deeply and to gauge requirement.	(*a*) Reset saw to cut deeper and to gauge requirement (*b*) Reset cutter to take less metal from surface of head.
Prevention	Frequent checking and tightening up fully. Saw frame.	(*a*) Frequent checking and tightening up fully. Saw frame. (*b*) Correct setting and adjustment.

departments. The training department executes an appreciable quantity of production work and has its own production-control clerk, work checker and inspectors. The department is administered as a production entity, and trainees are thus accustomed from the beginning to the functional activities in shop management.

TRAINING AT G.K.N.

Slotting, Shaving and Threading.—Specialised operator training was adopted primarily in the wood-screw section of Guest, Keen and Nettlefolds. The automatic machines for slotting and shaving the heads and for threading screws present an interesting problem in multiple-machine training. Women operators look after 12–24 machines which are automatically fed but which need cutting tools changed and adjusted, hoppers filled, screw channels cleared, etc. Traditional training methods, by " putting Sally with Annie " for nine weeks, had proved unsatisfactory—output and quality were inadequate and labour turnover among trainees very high.

In 1952, a separate training centre was established, the necessary analysis made and a training course prepared. An experienced male setter was selected as instructor and given an intensive course on instructing. Subsequently, after a training period of three to five weeks, girls were able to produce at piece-work speed to a satisfactory standard of quality. The scrap produced has, since the introduction of this training scheme, diminished markedly, but this cannot be entirely ascribed to training, since statistical quality control and some new machinery have also been introduced.

The training centre has also been used for re-training existing workers on new and faster machines. The introduction of new machinery had previously presented serious problems to the company, and it was decided that early examples of new machines should be installed in the training centre, and that all operators before being asked to work them should be given a comprehensive training on them for 2 to 3 weeks. The first pair of trainees consisted of workers first recruited in 1913 and 1914. As the operations had not been time-studied, it was not possible to specify exact standards of proficiency in the training, but the difficulties of introducing the new and faster machines were successfully overcome, and the workers appreciated the greater understanding of the job which they gained.

One particular feature of these training courses is the fault analysis which, with the quality specification, forms the basis of quality training. Table I shows part of the fault analysis for slotting and shaving. Each fault forms the basis of a short talk and demonstration of how it occurs, followed by recognition exercises in which screws are inspected by trainees and faulty ones removed. Trainees then recount to the instructor the details of the fault under each of the seven headings. Where appropriate, trainees are taught to make faults shown on the list; they adjust the machine to produce a faulty screw, then re-adjust it and their understanding of the cause of the faults is thus increased.

A further feature of the training procedure was suggested by the instructor, who realised from subjective analysis and observation that trainees derived much less information from the appearance of swarf than did experienced workers. He therefore collected different types of swarf, and prepared demonstrations on " swarf indications." It was particularly interesting to note that the instructor recognised the importance of perceptual factors in the skill, and the need to derive information rapidly from what the machine itself was doing.

Cold Heading (i.e. Forging).—A training course on similar lines has been prepared for trainees on cold heading. The workers are all men, so the periods of work are longer and the " tone " of instruction is modified to suit their interests. The knowledge content of the job is much greater, and more periods are spent on demonstrations and talks.

So far, 28 men have undergone the training, which is now accomplished in four to six months

compared with a previous learning time in the shop of 48 months. This training section is now being enlarged in order to provide capacity for training headers for all the company's factories in Birmingham, and also selected trainees from other factories in Great Britain and overseas.

Wrapping.—A training course is now being developed for screw weighing and wrapping—an operation as different from the other two as they are from each other. This is a wholly manual task, consisting of weighing, counting screws in grosses, and packing them in cartons which are subsequently wrapped into parcels. Although modern electronic counting machines are used for some types, many screws still require hand wrapping.

The operation is broken down into sections, each with its target time, and practised until this speed is reached before the sections are put together. This operation exhibits interesting features in making decisions (weighing) and in rhythm and pattern of hand movement (boxing and lidding), and a considerable knowledge content since there is a large number of carton sizes and a very large number of screw sizes.

The training course for this operation has one feature in common with that for slotting and shaving—training for recognition of screw types and sizes. In both operations, the presence of " foreigners " among the screws is an undesirable possibility, and at the commencement of each course trainees are given special exercises to train them in recognising different types and sizes of screw.

Throughout the development of these training schemes, the trade union and shop representatives have co-operated, and have been given prior information on projects and details of the training technique. Union officials and representatives have made frequent visits to training centres both when training and when re-training are going on.

TRAINING AT G.E.C.

The General Electric Company, Limited, introduced specialised operator training at Witton nearly three years ago. This site houses some eight factories, each manufacturing different products and requiring from the operators varying types of skills. It was not feasible to establish a central operator-training department, but so far four training centres have been set up, each serving the appropriate factory manager but functionally linked with an operator-training section which prepares and organises new training courses.

The following are the main groups of operations for which specialised training has been established:—

Hand Winding.—This, in one form or another, still constitutes the basis of manufacture of many types of motor. Previously, training had been done in the shop, where the operators were working on a work-study incentive scheme, and a learner's allowance was available for the first twelve weeks.

The coil-to-core assembly operation was first analysed, and a training course drawn up. This consists of preliminary exercises, instruction schedules for each section of the job (with targets), quality specification and fault analysis. An operator from the bench was selected by the foreman and instructed on the new training procedure. Recruits have usually been trained in pairs, and so far trainees have been through the training section on various types of this operation. Fig. 2 shows the comparative learning curves from shop learners on a similar operation and trainees given specialised operator training. It will be seen that, after preliminary and section training, the experienced workers' level was attained after three weeks instead of after 12 weeks.

The financial advantages of such a reduction in training time are quite appreciable. Over the 12-week period a comparison of results shows a reduction in training time of 9 weeks; an increase in production of 38 per cent.; an increase in operator earnings of 14 per cent.; a saving in direct labour cost of £15 per trainee; an economy in increased overhead recovery of £34 per trainee;

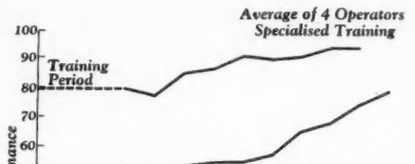

Fig. 2 Comparative learning curves for hand-winding of fractional horse-power stators.

amounting in all to a total saving of £49 per trainee. It will be noted that the saving in direct labour cost is fairly small; this is because —as is desirable—the immediate benefits of the trainee's increased productivity return to her in the form of bonus earnings. As the trainees attain good bonus earnings after three weeks, no learner's allowance is subsequently necessary.

Operators on hand winding whose performance has been below par have been retrained by the same specialised methods. For example, two workers who had been more than three years in the shop and whose performance on a new type of winding was below daywork level were given two weeks' intensive retraining, after which their performance reached the 80 level, thus increasing their earnings and obviating the costly " make-up " of the pay packet each week.

Switchgear Assembly.—For the smaller types of switchgear assembly, each operator undertakes a variety of tasks. Previously, new recruits had taken about five weeks to attain piecework level of production. The manager and foreman considered that training could be better done outside the shop, and a training centre was established on the floor beneath. Here, benches and training apparatus were set up, a training course established, and an instructress taught to use the new procedures. Trainees now attain the target level of performance after approximately two weeks instead of five.

An analysis of the types of assembly work revealed that they could be categorised according to types of tool used. In order, therefore, to facilitate the development of flexibility by trainees, they are given two days of preliminary tool training; at the end of this they are normally capable of using the tools—screwdriver, power screwdriver, nut runner, etc.—at experienced workers' speed.

The training centre is now used for an additional purpose, as a workshop for developing human—as distinct from technical—methods of work on new or existing products.

Machine Shop.—In the machine shop, the training of capstan operators had long presented a difficult problem. Labour turnover was extremely high, and few trainees attained an adequate level of productivity.

A small section of the shop, containing six capstans, was screened off, and a training course was set up. Initially, training was given to boys fresh from school, but subsequently men, generally on leaving the forces, were recruited for the job. For the boys, the training time was reduced from 12 weeks (to 50 per cent. of target level) to four weeks (to target level) and for men this was reduced still further to three weeks.

The introduction of specialised operator training and of a new incentive scheme was followed by a marked drop in the turnover of trainees. This in turn enabled space to be allocated for training setter-operators, and a course for this is now running satisfactorily using as trainees men who had been through the operator course. The knowledge content on this course is much greater and careful attention is devoted to teaching the " derivation of information " from blueprints and order sheets.

Training courses are now being developed for other operations at the Witton factories: for assembly operations on domestic appliances, for dry cell manufacture, for desk-fan winding and for power presses.

The courses described illustrate, for the three firms mentioned, the way in which specialised training methods are being used for " bread and butter " operator jobs in engineering. Courses along similar lines are in operation in other firms for machine setters, and elsewhere courses for auto setters are being planned. Looking further ahead, preparations are being made to train by these methods operators who assemble unit head mechanisms for automatic transfer machines, and undoubtedly there are many other engineering jobs where such methods could be applied with benefit.

The improvement of operator training has also been engaging the attention of managements in many other industries, since the basic features of skills and training have much in common throughout industry. On the human side, the analysis of skills and the acquisition of skills present similar problems whether the operator is engaged on a turret press or on a typewriter, on counting screws or on weighing ounces of tobacco. Again, on the administrative side, the questions to be answered before deciding on the organisation of a training department are very similar whatever the industry, and the answers may differ as much between firms in the same industry as between industries. Thirdly, the introduction of new training methods presents the same difficulties in social integration, whatever the industry concerned.

In most cases, specialised training has been introduced by individual firms for their own needs. In the cotton industry, however, an interesting experiment is taking place, whereby a central organisation—the Productivity Department of the Cotton Board—has developed the analyses and training programmes for standard weaving and spinning operations, and is teaching mill training officers to use them. Similar arrangements might well be possible in branches of engineering and allied industries, but they do not so far appear to have been attempted.

In countries overseas, there is a growing interest in operator training, though perhaps it is less marked. In 1955 the National Institute of Industrial Psychology undertook a survey of " in-plant training " in Great Britain as part of a wider European survey sponsored by the European Productivity Agency. Already in Europe some of the fundamental ideas of specialised operator training are being tried out, especially in Scandinavia and in West Germany, where they are being combined with T.W.I. instruction. In the United States, Mr. Geoffrey Ladhams and a small group of consultants from Personnel Administration, London, are engaged in introducing these techniques to American industry, and particularly to the textile and garment trades.

The immediate advantages of improved operator training—in reduced learning time, increased productivity and reduced costs—are in most cases quite obvious. What is perhaps even more interesting, and in the long run more important, is the opportunity which specialised operator training provides for the " education "—in the fullest sense—of operators in industry. Although most factory workers have been able to derive only minimal benefit from State education, they can, by rapidly gaining competence and confidence on an industrial job, attain a degree of economic independence and social standing. If, at the same time, they can acquire a deeper appreciation of the world around them through apprehending more fully the information which their senses bring them, they can and do develop as personalities with a wider horizon in life. Such education through work—such development of personality through the ends of one's fingers and through seeing what one is looking at—has been neglected since the Industrial Revolution brought the factory system and the division of labour. Greater attention to it might well assist in coping with the social problems of our industrial civilisation.

Letters to the Editor

ROAD SAFETY AND SKILL

SIR, The favourable reviews of *The Skilful Driver* and the complimentary letters I have received confirmed my fears that my book might only be read by those who were already experts. Mr. Power's amusing tirade, however, makes it clear that this is not so. It is, however, comforting to think that out of 160 closely written pages, he has only picked out some eight points with which he disagrees. Were there no good points, Mr. Power?

Those who have read the book will realise that in most cases your correspondent has put a somewhat different construction upon my statements from those intended. If Mr. Power is going to use quotation marks, they might at least refer to exact quotations from the book rather than to his own often wrongly condensed versions.

Dealing, however, with the points Mr. Power makes: I fail to see what is wrong with holding the steering wheel by one of the spokes. Has he not noticed that the majority of high-speed cars have not less than four spokes in their steering wheels? Resting the right elbow on the window ledge may well give better control than having it constrained between oneself and the side of the door.

It is always of course possible to make a statement look peculiar if you take it completely out of its context. My reference to driving close to the kerb was that one or two feet out is ample, though certain circumstances may modify this. The rest of the page on which this appears consists of explaining under what circumstances a greater distance out is necessary. In any case, I would remind him that every foot nearer to the kerb means 2 ft. more effective road width, and we can surely do with this to-day!

As regards checking speed on ice by braking, it is evident that Mr. Power is under the impression that better adhesion is obtained by slowing up two wheels than by slowing up four. Experienced motorists know better.

I am afraid that I do not follow him as to it being illegal to use a horn to warn a thoughtless motorist to take more care in future, nor am I aware that coasting is illegal. (The Rover Company should perhaps take care.) Again he seems to suggest that I have advocated switching off the engine during coasting, whereas what I pointed out was that if it is switched off, servo-brakes may be inoperative.

It is not worth wasting your time in quoting *in extenso* from the paragraph which deals with driving on the footpath, but it is evident that Mr. Power has not realised that I was being sarcastic. As regards the fitting of an altimeter, if this be fatuous nonsense, then I am in good company with the Duke of Edinburgh, who not only has an altimeter on his Lagonda, but a compass as well.

Mr. Power may know more about the standards required by police forces than I do, but it is curious that I know of at least two county constabularies who have commented favourably on my book.

It is evident that Mr. Power is one of those who believe that skilful driving can be attained by conformity to certain rules and regulations. I, on the other hand, believe that there is no golden rule, but that what is needed is a realisation of one's limitations, an appreciation of the difficulties of others, and above all, the exercise of tolerance and courtesy.

Yours faithfully,
J. S. BLAIR, D.Sc.

3, East Carlton Park,
Market Harborough.
June 28, 1956.

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PUBLIC HEALTH COURSES

SIR, The comments under the above heading in your issue of June 15 (page 487) contain the following statements: "... the corresponding course (i.e., in public health engineering) at a London college has had a full complement of students during the past year and has received more applications than there are places available in respect of the year commencing October. Moreover, during the past year, all the students were from the United Kingdom and even next year only two will be from overseas."

Since the Imperial College is the only London college offering a full-time post-graduate course in public health engineering similar to that at Newcastle, may I make it clear that the above statements do not represent the position here. We certainly had a full complement during the session which has just ended, but 13 of the 16 students came from overseas and of the three Englishmen, one was sent from the Public Works Department, Nigeria.

There are still several vacancies on this course for the next session. Of the seven applicants who have so far been accepted, two are from the United Kingdom, and a third was born in the U.K. but is now serving in the P.W.D. in Malaya.

It may be of interest to point out that during the six years this course has been given, 31 per cent. of the students have been from the United Kingdom and Eire, 26 per cent. from the self-governing countries of the Commonwealth, 30 per cent. from other Commonwealth countries (including those recruited in the U.K.) and 13 per cent. from foreign countries.

This shows a fair representation from the U.K., but it must be remembered that nearly all of these men were able to attend the course only through the generous help of the Rockefeller Foundation. There is still no financial assistance from industry or from organisations associated with public health engineering in this country comparable to that which is available for post-graduate students of concrete technology, hydro-power and other subjects.

Would it not be to the advantage of the country as a whole if a few of our larger municipalities were to lead the way by giving selected engineers paid leave to attend these courses in public health engineering—and, for that matter, post-graduate courses in other subjects which are available at many universities?

Yours faithfully,
F. E. BRUCE,
Reader in Public Health Engineering.
Imperial College of Science and Technology,
London, S.W.7.
June 27, 1956.

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Obituary

MR. J. S. HOLLINGS, C.B.E.

We note with regret the death of Mr. James Spencer Hollings, which occurred on June 21, at the age of 84. Mr. Hollings, who was a recognised authority on coke-oven and blast-furnace plants and the layout of integrated steelworks, was born in 1872 and educated at Sedbergh. He began his industrial life in coal-mining, but after qualifying for colliery management in 1893, he joined the Brymbo Steel Company, Limited, and in 1914 became managing director. Subsequently, Mr. Hollings became managing director and vice-chairman of the Guest Keen Baldwins Iron and Steel Company, Limited (now Guest Keen Iron and Steel Company, Limited).

During the war of 1939-1945 his advice and services were sought by the Ministry of Home Security, and his efforts were recognised by the award of the C.B.E. Mr. Hollings relinquished the position of managing director and vice-chairman of the Guest Keen Baldwins Company in 1945, but retained his seat on the board.

He became a member of the Iron and Steel Institute in 1903, was elected a member of Council in 1930, vice-president in 1938, and an honorary vice-president in 1946, in which year he received the Bessemer Gold Medal. He served on the executive committee of the British Iron and Steel Federation and on the Council of the British Iron and Steel Research Association.

Weekly Survey

Cover Picture: *Instrument graticules are made by cutting the glass surface, previously covered with a wax-like acid resistant, using a pantograph reduction. The cutting tool is a hardened steel needle, honed to a chisel-shaped edge. After cutting through the coating, the glass is etched, using hydrofluoric acid fumes, the dilution and temperature being carefully controlled. By this means, lines* 0·0002 *in. thick may be successfully produced, and using selected diamond tools, even finer lines may be cut directly into the glass.*

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Machine Tools 1960

To-day the 1956 International Machine Tool Exhibition at Olympia comes to an end. Weary-footed buyers will be returning to the suburbs, provinces and foreign lands from which they came; exhibitors, glad to resume their customary duties, will be preparing to dismantle their stands; organisers after heaving a joint sigh of relief will begin to plan for the next exhibition four busy years ahead. Some 1,500 machines weighing altogether more than 6,500 tons must be spirited away and work begun on what we trust is a satisfying new batch of orders.

The next exhibition, due to be held in 1960, is necessarily very much in the embryo stage, even its venue has not been decided. Since 1912, when the exhibition was first held at Olympia, the Machine Tool Trades Association has grown immensely; machine tools have increased in weight and size; and the problem of exhibition space has become a major one. At Olympia, only the ground floor is suitable for the larger machines, while the very heaviest items must be located in those comparatively limited areas where the concrete foundations are sufficient to support them. Other exhibitors, whose products are lighter, must perforce take stands elsewhere. Although, before the exhibition, certain manufacturers relegated to the balcony were said to be dissatisfied, the visitors prepared to rise to the occasion have proved very numerous.

The only immediate alternative to Olympia appears to be Castle Bromwich. Although this location offers more extensive ground-floor space, there remain other problems, such as the height of gateways, the distance from the Continent and general inaccessibility, the supposed shortage of nearby accommodation, and the myth that no-one can have a good time in Birmingham. The pros and cons of the argument have yet to be fully weighed and no doubt before agreement is reached much polemic skill will be brought to bear. However, the purpose of the Machine Tool Trades Association is to serve its members, who must inevitably be the final arbiters.

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Reactor Problems to Solve

This week the Institute of Physics in collaboration with the British Nuclear Energy Conference held a four-day conference on "The Physics of Nuclear Reactors" (see page 29). Conferences in general serve as a means of disseminating knowledge and cross-fertilising ideas, but in a field like atomic energy where progress is not only rapid but of fundamental importance to the national economy, a conference can have a further purpose—the high-lighting of problems which have still to be solved.

In a foreword to the Conference Handbook, Sir John Cockcroft writes: "The purpose of the Conference is to keep members of the Institute and its sister Institutions abreast of scientific developments in nuclear reactors and to call their attention to the problems needing solution. The Conference is particularly intended for industrial and government physicists, working or likely to work directly or indirectly with reactors, and for lecturers and other teachers."

It is, of course, essential that as many qualified people as possible shall know what problems

remain to be solved, but it is equally important that the means of solving them shall be available. Some firms are in a position to assemble their own nuclear data; others can consult official sources; but only by ready access to an up-to-date body of published information can the majority of scientists and engineers make useful contributions. Publication is the traditional lubricant of scientific progress; its unction is no less necessary today.

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Kariba gets the Money

The recent announcement that the International Bank for Reconstruction and Development has agreed to lend 80 million dollars (about £28·6 million) towards the cost of the first stage of the Kariba hydro-electric power scheme justifies the faith that the necessary finance would be made available which was inherent in the decision of the Federal Government of Rhodesia and Nyasaland to start preliminary work on the project about a year ago. The first stage of the scheme involving the installation of generating capacity amounting to 500,000 kW and the erection of nearly 1,000 miles of transmission lines is estimated to cost £80 million. In addition to the loan from the International Bank, £15 million is to be provided by the Colonial Development Corporation, £3 million by the Commonwealth Development Finance Company Limited, while the Rhodesian Selection Trust and Anglo-American groups are lending £20 million, the British South Africa Company £4 million and Barclays Bank (D.C. and O.) and the Standard Bank of South Africa £2 million each. This leaves a balance of just over £5 million still to be found by the Federal Government.

The preliminary work on the scheme, involving the provision of access roads and housing and the construction of coffer-dams and of the by-pass tunnel, has been largely in the hands of British contractors but although no contracts have yet been placed for the main work it is reported that many of the tenders submitted by British companies are not competitive. It is expected that the main contract for the civil engineering work will go to an Italian group and that the Italian companies which have been responsible for the erection of transmission lines from the Belgian Congo to the Northern Rhodesian Copper Belt will get the contract for the transmission lines from Kariba. Possibly even more disturbing is the fact that many of the orders for heavy equipment, including turbines and generators, are expected to go to continental manufacturers in spite of the fact that British manufacturers enjoy a tariff advantage of 10 per cent. Although the total British contribution to the scheme may still be considerable the loss of these important orders, if confirmed, underlines the importance of preventing further rises in costs in the British engineering industry and provides further justification for the stand now being made against reduction of hours and increases in wages.

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Productivity and Management

Insofar as rising productivity involves increased mechanisation and growing control and planning of the production process by management, the outlay on the administrative side of business tends to increase. This is a generally known fact and sometimes a source of criticism. Is it not possible, it is often said, that the lower costs achieved by higher productivity on the shop floor are lost to a noticeable extent by increased overheads in the office ? The latest " Productivity Measurement Review," published by the Productivity Measurement Advisory Service of the European Productivity Agency, contains a paper called " Industrial Productivity in Relation to the Cost of Management " from a research worker at Columbia University, New York—a paper which gives some facts on the subject.

The paper starts from the observed fact that the costliness of managing concerns has been increasing both absolutely and in relation to the input of the production worker. The analysis of data in the United States and other countries leads to the conclusion that there is no proven systematic relation between the degree of change in industrial productivity and the degree of change in the cost of managing. On the other hand, by studying data from manufacturing industries in the United States and in the United Kingdom, there emerges quite clearly a contrast between experiences in the two countries. Over the last half-century the growth of labour productivity in the United States has gone on at a much higher rate than the growth of administrative overheads. The reverse is the case in British industry. This difference between the experience in these two countries is put down to the higher rate of increase in output per worker in the United States compared with the United Kingdom. The writer points out that in his opinion, where the level of productivity and its rate of increase is high, as in the United States, industry can well carry the cost of the increasing cost of management. Where productivity and the rate of increase is low, however, administrative overheads can be a tax on the output of goods per person.

Some emphasis is laid in the article on the fact that industrial productivity is mainly the function of the degree of mechanisation while the cost of management is determined by the degree of what it calls " extension of managerial decision-making." This last is, in plain terms, the extensiveness and intensiveness of managerial control. It is emphasised that these two, although closely connected geographically, are not necessarily different facets of the same thing. This conclusion might well be challenged. It is very likely that a concern which increases mechanisation will increase the functions of management, at least intensively, at the same time. The facts in the article do, indeed, reinforce what is generally accepted, namely, that increased mechanisation and higher productivity may well involve increased outlay on management which must justify its increased cost out of higher productivity from the factory. Whether you start by increasing managerial overheads to get higher productivity on the shop floor, or go for increased productivity on the shop floor first and then build up the managerial side to go with it, is largely a question of local circumstances.

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The Trail of the Shooting Star

By demonstrating their streamlined single-seater turbine car at Montlhéry recently, Renault gained a lot of publicity but added nothing to current knowledge of the subject. A turbine car with three big fuel tanks and no heat exchanger, emitting large quantities of hot exhaust gas and suffering the usual time lag in acceleration, and the usual lack of engine braking, makes no technical news six years after Rover demonstrated the same thing.

There are however, more interesting developments in hand, for the car was built under the supervision of M. Fernand Picard, Renault's director of research and development, who was responsible for the 1,000 h.p. turbine locomotive with free-piston gas generator which was built in 1952 and has now done 150,000 miles in regular service on French railways. He also has a new locomotive of 2,000 h.p. working on the same principle nearing completion, and at Montlhéry he agreed that the free-piston generator, giving Diesel efficiencies, and reasonable gas temperatures at the turbine, offers attractive possibilities for the motor vehicle. The square-cube law and other factors reduce efficiency in small sizes, but General Motors has already shown a car with such an engine, and it may be assumed that Renault is well advanced with its application in sizes suitable for trucks and coaches, if not for the small European family car.

The single-seater car demonstrated at Montlhéry has afforded practical experience in the operation of small vehicle turbines, and has given Renault engineers the opportunity for practical studies on other aspects of vehicle design, including construction of frames in chromium-molybdenum steel tube by electric welding with and without addition of metal, wind tunnel investigations of low-drag body shapes, and stability investigations with the aid of detachable tail fins of various shapes. It has also involved work on construction of body panels in plastics, torsion bar suspension, and independent rear suspension of the low pivot swing-axle type.

The power unit is a Turbomeca Turmo I built under Szydlowski patents, giving 266 s.h.p. with the compressor turbine running at 35,000 r.p.m. and the free power turbine running at 28,000 r.p.m. It has a single-stage centrifugal compressor feeding a toroidal combustion chamber, which supplies gas to single-stage axial-flow compressor and power turbines. Power is transmitted to the rear wheels via a three-stage reduction gear consisting of two stages of parallel gears, and a bevel gear, then via the differential to the universally-jointed drive shafts. The transmission casing also houses a reverse gear. There is a large flexible fuel tank in the nose, and there are metal tanks on each side of the cockpit.

Front suspension is by Porsche-type twin trailing arms with torsion bars, and universally jointed shafts connect the wheels to the disc brakes, which are mounted on the chassis at front and rear. Disc brakes and light-alloy wheels are British Dunlop, of the type used on the Le Mans Jaguars. Rear suspension is also by torsion bars, with a single broad-based wishbone at each side, carrying the hub, and pivoted under the transmission casing near the centre line of the chassis, to lower the roll centre, and reduce variation of wheel camber with suspension deflection. Air for the compressor enters through slots in the body alongside the cockpit, and the exhaust escapes via two ducts just forward of the rear wheels. The car weighs 2,090 lb. Power unit complete weighs 395 lb.

At Montlhéry, the car did not exceed 125 m.p.h., which was obtained with a gas temperature of 500 deg. C. at the entry to the turbine. It may go to the new high-speed circuit at Monza later, for tests of maximum speed. Clearly, the Régie Renault, directed with a dynamism rate in nationalised industries, and working simultaneously on cars, trucks, buses, coaches, tractors and locomotives, is favourably placed to solve the problems of turbine propulsion for road vehicles, and some more interesting things may be expected in the trail of the Shooting Star.

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A Pump Comes of Age

The pump is an engineering mechanism which in various designs and outputs has been used

Renault's gas-turbine car " Shooting Star."

for mechanically handling water for some 2,500 years. To claim novelty in this field would therefore seem to be difficult. Nevertheless, it was successfully achieved 21 years ago by Mr. Rene Moineau in the course of endeavours to discover an efficient method of supercharging aircraft engines. The result was the production of the Mono pump, the coming of age of which was celebrated at the Audenshaw, Manchester, works of Mono Pumps, Limited, on June 16. In essentials this pump consists of a rotor which is similar in appearance to an Archimedean screw. Its cross section at right angles to its axis is, however, a true circle at any point in its length and it is of eccentric form. The stator has twice the eccentricity of the rotor and is made of resilient material. These two elements engage so that when the rotor is turned it moves with a hypocycloidal motion, the result being that pockets of liquid constantly progress in a wave motion from the suction chamber to the delivery end. These pockets are constant in size and shape so that both fluids and solids in suspension can be transmitted. During its existence Mono Pumps, Limited, has produced models for dealing with a wide range of thick and thin fluids, both corrosive and pure, and in a hot or cold condition and in the domestic as well as the industrial fields. The latest development, which is the result of work in the firm's Research Department, is a pump for handling powder on the same principle as a fluid, so that it will not fly into the atmosphere and endanger those who have to handle it. For this purpose a small quantity of air is injected into the system and forms a cushion to fluidise the powder granules. Thus they behave like a fluid and in some cases can be pumped along a horizontal or vertical pipe line. All of which goes to show that there is still room for inventiveness and enterprise in the engineering industry.

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Rolls-Royce's Ramifications

It was the Americans who first made journalistic play with the fact that Rolls-Royce Limited had its publicity policy fashioned by its security department. It is certainly true that even today less is known about the activities of this organisation than of other public companies of comparable size. This determination, however, to tell the minimum amount which can add up to a statistical picture does not prevent the annual meeting of the company from producing an interesting and informative assessment in vague general terms of the company's prospects. As with its motor-cars, the layman is not encouraged to look under the bonnet but he is bound to be impressed with the overall appearance of what he sees.

The main impression from Lord Hives' review for the financial year ended December 31, 1955, is the general prosperity of the company, its size and the wide dispersion of its interests. The company employs about 36,000 people and its turnover for customers other than the British Government was £23 million. It will be surprising if the work done for the Government is not at least twice as large again. An interesting milestone in the company's history last year was the completion of the last contracts for piston aero engines and centrifugal jet engines. The company continues to supply the largest proportion of engines to the R.A.F., and aero engines for civil airlines continue to expand. Among these may be mentioned the plans taking shape for the manufacture in Holland and America of the "Friendship" aircraft designed by Fokker and using Dart engines. It should be noticed in passing the emphasis which the chairman laid on the importance of the spare parts business. The accumulative demand for these from all quarters may make it necessary to establish additional manufacturing capacity if the demand for other production resources is maintained at the present level. Among the new engines, it is already known that the Tyne is to go into the new Vickers Vanguard, and the new Conway engine embodying the by-pass principle is to go into the Douglas D.C.8. A special word is given this year to the arrangement to make a torque-converter under licence from an American company to suit Rolls-Royce power units between 60 and 600 h.p. The torque-converter is a fashionable device in the United States and no doubt has a good future in this country provided its price is acceptable and its development is not curtailed by the increasing popularity of electric motors. Progress continues to be made with oil engines and Rolls-Royce is now actively pursuing business with British Railways for an oil engine incorporating a torque-converter. In power plants, an output twice as high as 1955 is planned for 1956 and a further 50 per cent. expansion is envisaged for 1957. The company is, of course, also interested in the application of nuclear energy through its association with Vickers Limited and Foster Wheeler Limited. Altogether, the company faces a formidable technical and investment programme over the next few years.

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Defence and Industrial Production

In May the official index of industrial production is estimated to have been between 135 and 136 (with 1948 as the base year), compared with 138 in May, 1955, and 128 in May, 1954. Thus for the first time in many months the level of industrial output showed a decline on the corresponding period of the previous year. It seems likely that the decline in the output of motor-cars, together with a drop in the production of steel owing to the overtime ban, and the now familiar contraction in cotton yarn, accounts for much of the decline. An official policy of deflation, involving the transfer of men and resources from one industry to another, must mean interruptions to the flow of production with declines in one industry and expansion in another. This state of affairs has now arrived in earnest.

It is now apparent that the much-heralded economies in defence expenditure will have little effect for some time to come. Mr. Macmillan announced last week total savings of £76 million towards his target of £100 million mentioned in the April Budget. Of this, £36·5 million comes out of the defence programme and £14 million from the defence outlay by civil departments. On defence the Navy estimates provide £11 million, the Army £17 million and the Air £8·75 million. Economies take the form of dropping or deferring orders and pruning stocks. In the case of defence expenditure by civil departments, the main cuts are in mobilisation equipment, food stocks and oil storage and distribution equipment.

The Chancellor has said that these economies do not reflect any change in the size or shape of the fighting forces. Any major decisions could not be put in hand before there had been consultation with our allies. Really substantial cuts are therefore likely to be a complicated and long-drawn-out business. The cuts which have been made in fact represent little more than a raid on the equipment reserves which the cynically-minded but far-seeing Service chiefs have been trying to "squirrel" away against some future hard winter of public economy. The possible deflationary impact of defence economies therefore hangs over industry more as a threat than a fact.

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How British Transport Fares

In the notes on the annual report and accounts of the British Transport Commission for 1955 issued last week the Commission has this to say: "the Commission feel bound to record their conviction that their financial position cannot be corrected by short-term expedients or quick savings, but only by arresting inflation and by pursuing the economies of modernisation within the framework of tolerant public regulation and policy." In simple terms, this means that the B.T.C. pins its hopes of ultimate solvency on being allowed to run a deficit until the modernisation scheme can bring substantial operating economies. This attitude is understandable enough for a large industry which has been more than discouraged from raising its charges and which has been starved of capital for several generations.

It is clearly going to be difficult for the B.T.C. to reconcile this prescription for long-term salvation with its statutory obligations to operate without loss. The Commission can, of course, argue that in a period of inflation the Government's unwillingness to allow transport charges to rise has ensured that it will work at a loss, and that "tolerant public regulation" means a more than indulgent interpretation of the Commission's statutory obligations in the light of the circumstances which have been forced upon it. In 1955 the B.T.C. had a working surplus of £29·5 million but after allowing for central charges, mainly interest, the final outcome has been a deficit of £30·6 million compared with a deficit of £11·9 million in 1954. In consequence, the cumulative deficit is now £70 million. If account is taken of the recent undertaking to freeze charges and the continuing upward pressure of costs, the deficit will be of the order of £100 million before there can be a notable change for the better. This is a serious consideration. In 1955, thanks to the modernisation programme, the Commission spent £72 million on capital development—most of it on the railways. This represents a useful increase in impetus on 1954 but when measured against the £1,200 million complete modernisation programme on the railways or against the Commission's assets with a book value of over £1,900 million, it is small and foretells a comparatively slow rate of progress. At this rate of increase the Commission and the trade unions may get used to living with a deficit and when the improvement is due there will be reluctance all round to accept the economies as a contribution towards reducing a long-standing operating deficit. Discipline from those at the top and a morale throughout the Commission of the highest order will be required to avoid this attitude developing.

Meanwhile, the B.T.C. faces its difficult future against a background of slightly reduced traffic, measured in passenger miles, although British Railways fell by only 2 per cent. despite the strike of last summer. Freight carryings continued to decline during 1955. Some of this was due to the reorganisation of British Road Services, but on the railways there were signs that some valuable merchandise traffic has moved permanently over to road haulage. The staff numbered 801,000 at the end of December—a drop of 30,000 on the year.

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European Iron and Steel Outlook

Output of iron and steel in Europe rose sharply last year, by 66·9 million tons, or 15 per cent. more than in 1954. Crude-steel production has increased relatively more than industrial production as a whole, mainly due to a rapid growth in the demand for durable consumer goods, heavy investment and capital equipment programmes. The annual report of the Iron and Steel Committee of O.E.E.C., "The Iron and Steel Industry in Europe," contains some interesting prognostications concerning future demand.

Production is likely to continue very high over the next few months, but "several factors seem to confirm the assumption that it will not continue to rise at the same rate as in the recent past." The main uncertainty relates to the anti-inflationary measures adopted recently by several countries. The report considers it too hazardous to forecast the repercussions these measures will have on steel consumption "in the medium term" and does not therefore include quantitative forecasts of the development of the demand for steel.

The O.E.E.C. report on the engineering industries in Europe, which was discussed in these columns last week, pointed out that the European economy had received a considerable momentum from the development of the engi-

neering industries. In that sector shortages of skilled labour and technologists is hampering growth. In the iron and steel industry it is the shortage of coal and scrap which gives cause for anxiety, and which " seem more likely that any other factors to set the limit to the future expansion of steel output." The import of coking fines and scrap from the United States has made it possible to meet the demand in 1955 and will presumably continue despite their very high cost.

Nothing in the report suggests a check on the rise in living standards, only attempts to check inflation which may or may not be successful. Yet there is a note of caution in the Committee's conclusions. They believe that the completion of the industry's investment programme now in hand should soon ease the position even if the demand continues to rise. There is very little evidence in the report to support this view.

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Whessoe asks for Steel

The expected rise in fuel-oil consumption should lead to a prosperous era for companies manufacturing petroleum equipment. It was announced last month that in the first quarter of 1956, orders totalling £38·5 million had been received by oil-equipment manufacturers. This represented a 17 per cent. increase over the same period in the previous year, and was 26 per cent. up on the last quarter of 1955. In addition, development plans announced by the leading oil companies in the early part of 1956 amounted to £40 million. These figures perhaps give only a small hint of what must come if the predicted demand for oil is to be met.

Whessoe Limited, whose report was published last week, are fully alive to the need to expand capacity and increase production if the demands made upon them by the oil industry are to be met. Their belief in a virile investment and development policy is reflected in the company's results. In the year ended March 31, 1956, the value of contracts completed and the number of new orders received both reached a record level, while net profits rose by 30 per cent. to £414,789. Mr. C. M. Spielman, chairman of the company, reported that among new developments during the year were the installation of new equipment for constructing large site-built storage vessels, and the completion of a more extensive welding laboratory and a large stress-relieving furnace. But the chairman shares the fear which has been expressed by other members of the petroleum-equipment industry—that severe shortages of steel plate are having a cramping effect on the speed of development. Mr. Spielman pointed out in his review that the industries which Whessoe supplies have massive expansion programmes which require ever expanding steel supplies. " The steel industry," he said, " is growing too slowly and planning for the future on too small a scale." This is a view officially shared by the Council of British Manufacturers of Petroleum Equipment, and the view has been expressed that the present shortage of steel is virtually halving the rate of development in the petroleum-equipment industry.

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Private Industry's Rights

The disclosure by Government departments to third parties of know-how in possession of a company—working models, drawings, designs, technical records and details of workshop practice—will no longer be legal if the recommendations of the Howitt Committee are accepted by the Government. The committee of inquiry under the chairmanship of Sir Harold Howitt, F.C.A., was appointed by the President of the Board of Trade in November, 1955, to consider whether the Crown should have permanent powers to authorise the use and the disclosure to other manufacturers in connection with defence contracts, of a company's know-how. The committee's answers are in the negative, except in so far as they recommend that the Crown should be given " permanent powers to authorise the use of technical information in connection with Government contracts."

All the committee's other recommendations are wholehearted in support of the rights of private industry. Any power to require disclosure of information to the Crown or to any other person should be specifically excluded; the powers should be strictly limited to defence requirements and " defence " should be narrowly defined; before powers are exercised the parties should be given three months in which to renegotiate; the powers should be exercised only at the highest levels; there should be provisions for compensation and for appeal to a Judge of the High Court.

This " Report of the Committee of Inquiry on the Powers of the Crown to Authorise the Use of Unpatented Inventions and Unregistered Designs in Connection with Defence Contracts " (Cmd. 9788, H.M.S.O., 1*s*.) is a most important document, since a company cannot register all designs and patent all modifications, or know-how. Industry will, if permanent legislation is introduced to replace the Emergency powers still in force, be reasonably protected. It is clear enough that in a competitive economy—which the Government are endeavouring to foster—the preservation of secrecy on information which may be the result of many years of research, development and trial, is essential. The Howitt proposals are a most encouraging step towards the protection of private enterprise.

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The " Electricals " Summer Meeting

The 450 participants who attended the Summer Meeting of the Institution of Electrical Engineers last week will agree that the Midlands is an excellent place for such a gathering. Within a short distance of the headquarters in Birmingham lies the principal factory of the General Electric Company at Witton, while not a great deal further away are the main works of the English Electric Company at Stafford and of the British Thomson-Houston Company at Rugby. All three firms, too, have subsidiary undertakings in the area. In addition there are a number of smaller manufacturers who are making their contribution to the productivity of the industry, while at Hams Hall, to the east of the city, are three power stations which, when the latest is completed in two years time, will provide an installed capacity of nearly 1,000 MW towards the electrical needs of the area. In the course of four days it was, of course, impossible for an individual to make more than a cursory inspection of these activities, but enough could be seen for it to be appreciated how much is being done not only to provide for present needs, but to introduce greater economy into methods of production and to seek out ways and means of increasing the efficiency of performance.

It is important that this point should be stressed, since a cursory glance at the programme might lead (erroneously) to the conclusion that technical functions were too highly diluted with those of a lighter nature. Social functions, however, have their value, since it is on such occasions that much useful information is interchanged; engineers being, as is well known, inveterate talkers of " shop."

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Bridge and Structural Congress

The fifth congress of the International Association for Bridge and Structural Engineering was held in Lisbon and Oporto, Portugal, from Monday, June 25, until Monday, July 2, with some special business and excursions continuing on until the end of this week. As is the custom at these congresses there was a full programme of engagements that offered ample opportunity for visitors to see Lisbon and the Portuguese countryside generally. Indeed a notable feature of the congress has been the hospitality lavished on the visitors.

The working sessions, six in number, were held in the Instituto Superior Téchnico and about 60 papers had been accepted for inclusion in the preliminary publication. To these were added another 20 or so which will be included in the final report. The meetings themselves were conducted in the Continental fashion, that is to say, a *rapporteur* briefly reviewed the published papers with which the session was concerned and thereafter members were allowed to introduce the new papers that would go into the final report; a nominal period was available at the end of each session for " free discussion " (i.e., discussion of the content of the papers after the English style) but in general the time left for such analysis was quite inadequate and little useful coment was forthcoming The scope of the papers covered the whole range of current structural problems though, by intention, those in the preliminary publications were primarily concerned with the more fundamental issues related to design rather than to descriptions of expedients adopted during construction. It was apparent, however, that there has been no important innovation since the Cambridge congress of 1952, though there has been a great extension of the use of more advanced methods of structural analysis, and a great deal of experiment has been undertaken with the object of determining more accurately the contribution of each element to the load capacity of a structural unit. A marked trend is the wider adoption of models of various kinds for the solution of design problems. Abstracts from some of the papers will be given in a general report of the congress to be published in future issues of ENGINEERING.

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Jugoslav Ships for India

The Indian Government announced last week the formation of a second shipping corporation with a capital of £7,500,000, which will be wholly controlled by the Government. The corporation is to acquire a fleet of 12 ships for services between India and the Persian Gulf, the Red Sea, Poland and Jugoslavia. This will represent an addition of a little under 10 per cent. to the Indian merchant fleet, which at present comprises 133 vessels. In order to supplement the output of the shipyard at Visakhapatnam, pending the building of a second Indian shipyard, the Indian Government is reported to be leasing for five years the spare capacity of a Jugoslav shipyard at Rijeka (Fiume).

In 1955 India launched six ships (four steamships and two motorships) of a combined tonnage of 10,485 gross tons. Jugoslavia also launched six ships (one steamship and five motor ships) but of a combined tonnage of 30,600 gross tons. The Jugoslav shipbuilding industry is now capable of producing dry cargo vessels of up to 12,000 tons capacity and tankers up to 18,000 tons, and in addition a range of smaller ships for coastwise navigation. Export orders in hand during 1955 included three 10,500 tons tramp ships for Switzerland, one of 11,000 tons for the United Kingdom, and four minesweepers of an aggregate value of 7½ million dols. under the offshore procurement programme. At the end of 1955 there were 22 ships under construction with a combined tonnage of 99,067 gross tons, representing about 1½ per cent. of the total tonnage under construction in the world, excluding the U.S.S.R. The majority of the motorships under construction are likely to be powered by Sulzer engines, which are produced under licence by the Treci Maj shipyard in conjunction with the Litostroj enterprise at Ljubljana and Jugoturbina at Karlovac.

The development of shipbuilding in countries formerly of little importance in this field is at present receiving a strong incentive from the lengthy delays quoted by most of the world's established shipyards and from the desire of many countries to operate merchant fleets under their own flags. The current Indian five-year plan, for example, envisages the formation of yet a third shipping corporation to trade on the India-America route.

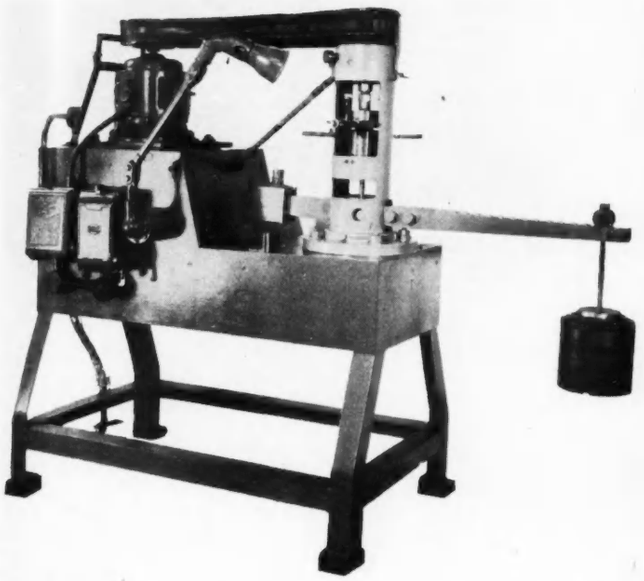

Fig. 1 Machine used for tests to determine the influence of the lubricant's properties on the occurence of pitting failure.

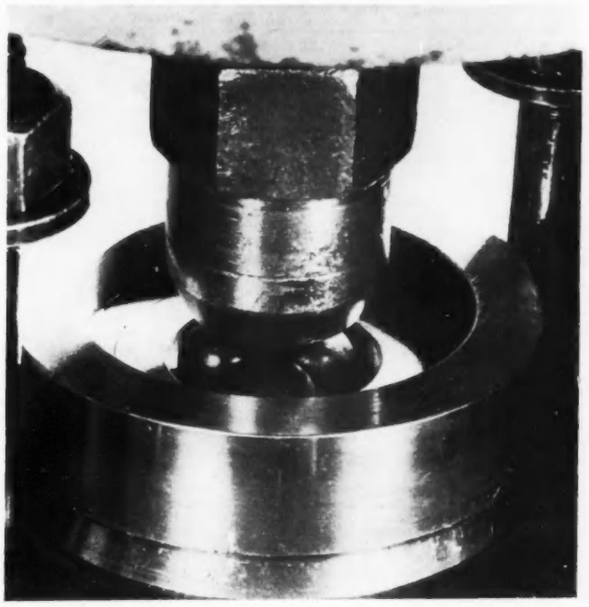

Fig. 2 Balls under test. An upper ball is held in the chuck and three other balls form the lower race.

EFFECT OF LUBRICANT ON PITTING FAILURE OF BALL BEARINGS

EXPERIMENTAL RESULTS FOR VARIOUS FLUIDS

By F. T. Barwell, WH.SC., PH.D., D.I.C., B.SC. (ENG.), M.I.MECH.E. *and D. Scott*, A.I.M.

It has always been recognised that a limiting factor in the life of rolling-contact bearings has been the disintegration of the surface, pits being formed by a process having fatigue characteristics. It has generally been considered that this phenomenon was attributable to the stresses at and immediately within the surface and was characterised by the properties of the materials. In some hydraulic systems the pumps embody roller bearings which are required to be lubricated with the hydraulic fluid being pumped. Premature failure of such bearings by pitting action has been reported and it appeared that the nature of the lubricant might have an important bearing on the incidence of pitting. Some of the non-flammable fluids have caused considerable concern from this point of view.

In order to assess the effect of the lubricant on pitting failure, some preliminary experiments were carried out at the Mechanical Engineering Research Laboratory using a simple apparatus in which conventional ball bearings were used as test specimens. In addition to conventional hydrocarbon lubricants which were tested for comparative purposes, numerous hydraulic fluids were suggested by the Ministry of Supply, other users and certain suppliers of proprietary hydraulic fluids. Test Marks and description of the fluids are given in Table I.

TEST RIG

Apparatus.—The test rig consisted of an adaptation of the Boerlage four-ball lubricant testing machine. In normal use a hard-steel ball held in a chuck at the end of a spindle is rotated at a constant speed of 1,500 r.p.m. under load in the cavity formed between three other similar balls clamped together in a cup containing

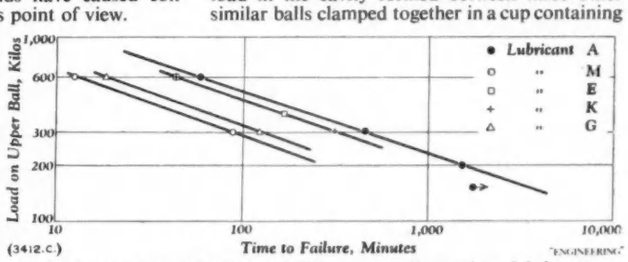

Fig. 3 Load against time-to-failure curves for various lubricants.

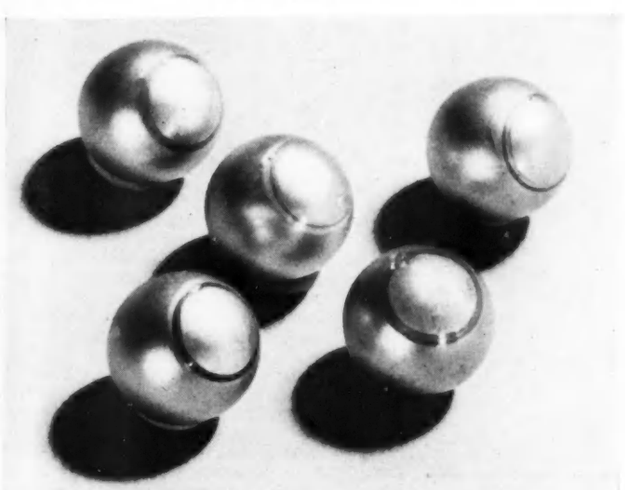

Fig. 4 Typical failed upper balls.

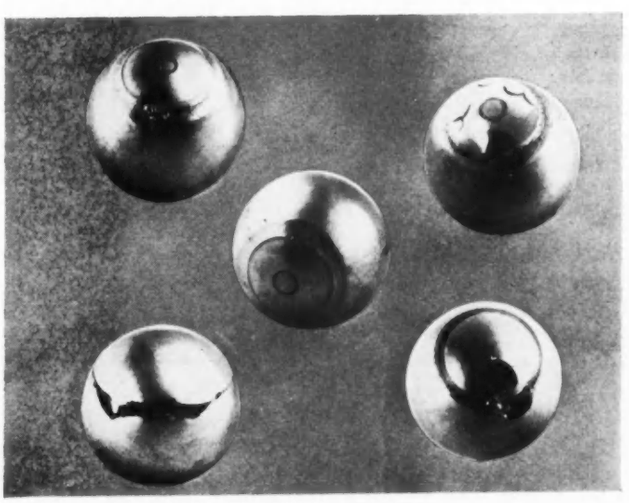

Fig. 5 Upper balls showing fractures and cracks.

TABLE I TYPES OF LUBRICANT AND TEST RESULTS

Test No.	Lubricant	Type of lubricant	Load on upper ball, kilos.	Maximum Hertz. stress, tons per sq. in.	Viscosity at 20 deg. C. Centistokes	Time to pitting failure, minutes	Average time to failure, minutes
A.1	A	Mineral oil formulated for use in aircraft engines	600	475	216	61	59
A.2						40	
A.3						54	
A.4						72	
A.5						66	
A.6						65	
A.7						66	
A.8						71	
A.9						50	
A.10						78	
A.11						48	
A.12						58	
A.13						47	
A.14						50	
A.15						63	
A.16						54	
A.17						57	
A.18	A	Mineral oil formulated for use in aircraft engines	300	375	216	450	464
A.19						380	
A.20						310	
A.21						540	
A.22						510	
A.23						555	
A.24						335	
A.25						600	
A.26						480	
A.27						480	
A.28	A	Mineral oil formulated for use in aircraft engines	200	330	216	960	1,513
A.29						1,170	
A.30						1,500	
A.31						1,500	
A.32						1,980	
A.33						1,500	
A.34						1,980	
B.1	B	Highly refined mineral hydraulic oil containing additives	600	475	89	34	42
B.2						34	
B.3						34	
B.4						42	
B.5						45	
B.6						56	
B.7						48	
C.1	C	Highly refined mineral hydraulic oil containing additives	600	475	47	49	32
C.2						22	
C.3						24	
C.4						37	
C.5						44	
C.6						31	
C.7						16	
D.1	D	Diesel-engine fuel	600	475	4	17	23½
D.2						23	
D.3						29	
D.4						18	
D.5						21	
D.6						33	
E.1	E	Hydraulic petroleum oil to Specification D.T.D.585	600	475	19	40	40
E.2						35	
E.3						31	
E.4						47	
E.5						50	
E.6						52	
E.7						45	
E.8						28	
E.9						23	
E.10	E	Hydraulic petroleum oil to Specification D.T.D.585	400	415	19	100	145
E.11						148	
E.12						131	
E.13						150	
E.14						196	
F.1	F	Synthetic fluid, believed to be silicate ester	600	475	17	24	32
F.2						49	
F.3						30	
F.4						32	
F.5						33	
F.6						24	
G.1	G	Synthetic fluid (non-flammable), believed to be polyester	600	475	19	16	18
G.2						24	
G.3						16	
G.4						17	
G.5						18	
G.6						19	
G.7						19	
G.8						15	
G.9						19	
G.10	G	Synthetic fluid (non-flammable), believed to be polyester	300	375	19	153	147
G.11						100	
G.12						125	
G.13						170	
G.14						188	
H.1	H	Mineral oil recommended as hydraulic fluid	600	475	55	53	46
H.2						22	
H.3						39	
H.4						57	
H.5						53	
H.6						52	
I.1	I	Non-flammable hydraulic fluid	600	475	81	30	45½
I.2						70	
I.3						62	
I.4						53	
I.5						32	
I.6						38	
I.7						33	
J.1	J	Non-flammable fluid, believed to be phosphate ester	600	475	174	60	67½
J.2						86	
J.3						46	
J.4						75	
J.5						86	
J.6						82	
J.7						45	
J.8						60	
K.1	K	Chlorinated diphenyl ..	600	475	343	40	40
K.2						35	
K.3						40	
K.4						45	

Fig. 6 Development of transverse cracks in track of upper ball run in mineral oil with load of 600 kg. (× 150)

Fig. 7 Transmission cracks in track of upper ball run with non-flammable fluid as lubricant with load of 600 kg. (× 150.)

the lubricant to be tested. With the adaptation used in the present tests the lower balls were allowed to rotate giving the combination of rolling and sliding experienced in angular contact ball bearings. The upper ball thus took the place of the inner race in a conventional bearing and was easily and cheaply replaced. The stress at the contact point between the rolling surfaces and the upper ball was very high and by suitable design of the outer or lower race, the stresses at this contact point were reduced enabling one outer race to be used for a considerable number of tests. Loading is by a single lever system over a range of 20 to 750 kilogrammes. Due to the high unit stresses on the upper ball by the heavy load used, time to failure was reduced to a convenient magnitude. Fig. 1 shows the machine used for the tests and Fig. 2 gives a close-up view of the chuck holding the upper ball and the three other balls in the lower race.

Method of Test.—Four commercial ½ in. diameter steel balls were used in each test and were thoroughly washed in benzene and allowed to dry before use. The lower race was thoroughly cleaned between each test. Bath lubrication was employed, a standard amount of lubricant (16 cc.) being used for each test. This was sufficient lubricant to keep the balls immersed. A spring cover fitting in the lower race holder and surrounding the chuck prevented loss of lubricant from the bath by centrifugal force. Each lubricant was tested using a load of 600 kilogrammes on the upper ball while a few of the lubricants were further tested using smaller loads to determine the effect of load on the life of the

ball bearings. Failure was detected by a change in noise characteristics of the machine and this method was found to be sufficiently effective to permit immediate detection of the presence of a very small surface pit.

Results.—Table I gives the results obtained from the various tests and Fig. 3 presents the results graphically for those lubricants tested at more than one load.

Type of Failure.—The upper ball from each test had a well defined running track and the usual failure pit. Occasionally one of the lower balls developed a pit. Failure to stop the machine immediately a pit developed resulted in smoothing over the edges of a pit by plastic deformation when mineral oil was used, but rapid expansion of the pits and in some cases fracture of the ball ensued when some of the non-flammable fluids were used. Fig. 4 shows failed upper balls typical of those produced by the test. Fig. 5 shows upper balls with pieces fractured out and cracks spreading to develop fracture of the ball.

METALLURGICAL INVESTIGATION OF FAILURES

Microscopic examination of the tracks of the upper balls after test revealed fine transverse cracks at the inner edge of the track. These appear to develop as the test proceeds. Fig. 6 (× 150) shows the development of transverse cracks towards pitting in the track of an upper ball after running in mineral oil under a load of 600 kilogrammes. Fig. 7 (× 150) shows well developed transverse cracks in the track of an

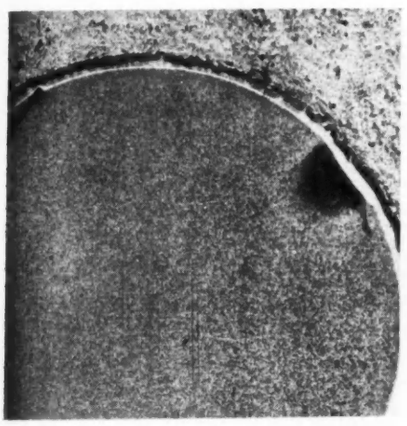

Fig. 8 Transverse section showing darker etching area of metallographic change below the track. Etched ammon. persulphate (× 10).

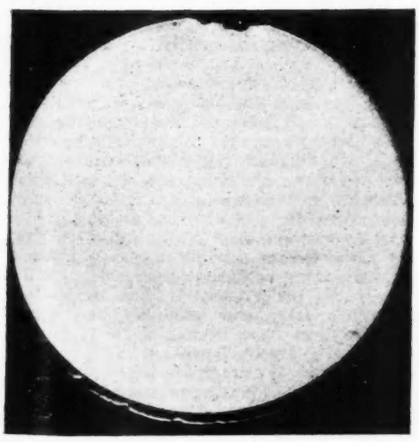

Fig. 9 Section through pit of upper ball after test with mineral oil, under load of 200 kg. Etched ammon. persulphate.

TABLE I. TYPES OF LUBRICANT AND TEST RESULTS (*continued*)

Test No.	Lubricant	Type of lubricant	Load on upper ball, kilos.	Maximum Hertz. stress, tons per sq. in.	Viscosity at 20 deg. C., Centistokes	Time to pitting failure, minutes	Average time to failure, minutes
K.5 K.6 K.7 K.8	K	Chlorinated diphenyl ..	300	375	343	323 300 335 285	311
L.1 L.2 L.3 L.4 L.5 L.6	L	Water base fluid	600	475	13	57 59 64 30 53 45	51
M.1 M.2 M.3 M.4 M.5	M	Water-Glycol non-flammable fluid	600	475	40	13 13 10 14 16	13
M.6 M.7 M.8 M.9 M.10	M	Water-Glycol non-flammable fluid	300	375	40	92 88 80 110 90	92
N.1 N.2 N.3 N.4 N.5 N.6 N.7 N.8 N.9 N.10 N.11	N	Water-Glycol non-flammable fluid	600	475	44	40 35 41 39 31 37 16 30 30 16 21	31
O.1 O.2 O.3 O.4 O.5 O.6 O.7 O.8	O	Water-Glycol non-flammable fluid	600	475	95	31 18 19 16 35 35 31 40	28
P.1 P.2 P.3 P.4 P.5	P	Polyalkalene Glycol ..	600	475	16	10 12 10 10 12	11
Q.1 Q.2 Q.3 Q.4 Q.5 Q.6	Q	Polyalkalene Glycol ..	600	475	356	33 32 17 18 29 29	26
R.1 R.2 R.3 R.4 R.5 R.6	R	(Dimethyl) siloxane ..	600	475	1·6	65 59 60 54 50 60	58
S.1 S.2 S.3 S.4 S.5	S	(Dimethyl) siloxane ..	600	475	115	48 53 48 50 60	52
T.1 T.2 T.3 T.4 T.5 T.6	T	Silicone lubricant intended as a hydraulic fluid to operate between 60 deg. C and 150 deg. C.	600	475	52	70 60 59 70 64 60	64
U.1 U.2 U.3 U.4 U.5 U.6	U	Tricresyl phosphate ..	600	475	97	39 53 45 25 62 67	48
V.1 V.2 V.3 V.4 V.5 V.6 V.7	V	Naphthenic base oil ..	600	475	53	34 30 72 40 72 53 57	51
W.1 W.2 W.3 W.4 W.5 W.6 W.7	W	Naphthenic base oil ..	600	475	101	67 37 70 30 70 60 72	58
X.1 X.2 X.3 X.4 X.5 X.6	X	Low V.I oil, probably naphthenic base	600	475	184	78 49 64 55 85 54	64
Y.1 Y.2 Y.3 Y.4 Y.5 Y.6	Y	Straight mineral oil ..	600	475	605	110 105 115 109 105 97	107
Z.1 Z.2 Z.3 Z.4 Z.5 Z.6 Z.7	Z	Straight mineral oil ..	600	475	757	144 140 138 150 105 140 148	138

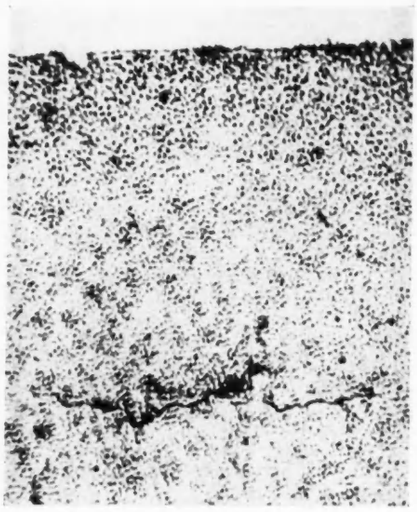

Fig. 10 Typical sub-surface crack. Etched Nital (× 500).

upper ball using a non-flammable fluid as a lubricant under 600 kilogrammes load. Here larger cracks are seen possibly proceeding to the complete fracture of the ball. It can be observed that part of the track was stained dark by mineral oil but remained bright with the other fluid.

Several tested upper balls were sectioned transversely through the track and a metallographic examination of the sub-surface area of the track carried out. Nickel plating was used to protect the surface and edges during preparation. With the heavy loads of 600 kilogrammes some metallographic change was observed in the sub-surface area of the track. Fig. 8 (× 10) shows a transverse section through a track with a darker etching area of metallographic change below the track. Some " Mechanical Troostite," as observed by A. B. Jones,* was found below the surface in the area of calculated maximum shear stress and sub-surface cracks were also found in this area.

Development of fine, transverse surface fatigue cracks and areas of sub-surface metallographic change were observed by running a series of tests on a time basis with mineral oil and a load of 600 kilogrammes. The first occasional surface crack appeared in the track of the upper ball after 10 minutes running and then became a regular feature of the track after 20 minutes running. One spot on the track usually developed a concentration of cracks. The number of cracks increased and developed with running time.

* " Metallographic Observations of Ball Bearing Fatigue Phenomena." Symposium on Testing of Bearings, *A.S.T.M.* June, 1946.

Upper balls from this series of tests were sectioned transversely through the track and again first evidence of sub-surface metallographic change appeared after 10 minutes running. This first area of change was not at the surface but some distance below corresponding to the area of calculated maximum shear stress. The area of metallographic change developed and became more evident as the time of test increased.

The running tracks of upper balls from the more lightly loaded tests did not show much evidence of fine transverse surface cracks but tracks examined after long running but before failure usually had a concentration of cracks at one spot on the track, possibly the position of the ultimate failure pit. Sections through these lighter loaded upper balls did not reveal any areas of metallographic change in the sub-surface area of the running track. Fig. 9 shows a section through the pit of an upper ball after test with mineral oil under a load of 200 kilogrammes. Sub-surface cracks, parallel to the surface were found in the area of calculated maximum shear stress below the tracks of some of the lighter loaded balls. Fig. 10 (× 500) shows a typical sub-surface crack.

DISCUSSION OF RESULTS

The test results conform to the recognised inverse cube law relating life with load of rolling bearings. The results also disclose that the adapted four-ball machine is clearly capable of differentiating between lubricants by showing detectable differences in time to pitting failure with different lubricants. The conditions used in the tests were more severe than in practice, the loads used being selected to obtain rapid failure and the results are therefore subject to confirmation at normal working stress. The general conformity to the inverse cube law, however, provides some support for extrapolation.

From the test results it appears that use of Fluid M would result in short bearing life as compared with that expected with mineral oil, Fluid A. Actual running of pumps confirms this, six weeks bearing life being reported when using Fluid M against 12 months bearing life when using mineral oil. Fluid E was also found in practice to give longer bearing life than Fluid G and both to be better than Fluid M but not so satisfactory as the straight mineral oil. Rapid deterioration of the bearing surfaces to a state of continuous fine pitting was found when using non-flammable Fluid M and sections through pitted races revealed numerous sub-surface cracks spreading from existing pits to ultimately enlarge the pits or form new ones. Fig. 11 (× 100) shows a typical example of this and can be compared with a similar mechanism of crack propagation by acid attack found in races of bearings run in a lubricant which had become highly acidic in use. Fig. 12 (× 200) shows a a section from such a race.

Evidence of metallographic change in the sub-surface area, first reported by Jones, was found only when heavy loads were used, which tends to suggest that, when found in practice, overloading has occurred.

Viscosity of the lubricant does not seem to be a dominant factor in the time taken to pitting failure as some very low viscosity fluids give as long a life as others with much higher viscosity. However, the test results of lubricants A to D, Y and Z mineral oils, show that with the same type of lubricant time to pitting is increased with an increase in lubricant viscosity. These results are presented graphically in Fig. 13. Increased stress cycles to failure with increased viscosity with the same type of lubricant was also found with lubricants P and Q and lubricants V, W and X but not with lubricants R, S and T.

It is possible that compressibility and variation in viscosity with pressure may be more important than the viscosity at atmospheric pressure, while

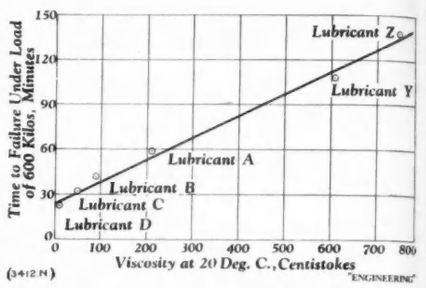

Fig. 13 Effect of viscosity on life of hydrocarbon lubricants.

corrosive effects combined with high stress, and chemical action of the fluids may make corrosion fatigue an important aspect to be considered.

Conclusion.—It can be concluded that the adapted four-ball machine offers many experimental conveniences for comparing in a preliminary manner the effect of various types of lubricant on pitting failure. The results are reasonably reproducible and the use of four commercial steel balls for each test is an economical method of obtaining a fairly uniform test specimen.

Acknowledgments.—The work described has been carried out as part of the research programme of the Mechanical Engineering Research Board of the Department of Scientific and Industrial Research. The article is published by permission of the Director of Mechanical Engineering Research.

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DYE PENETRANT INKS

Dye-penetrant flaw detection inks marketed by Manchester Oil Refinery (Sales), Limited, Retail Division, Twining-road, Trafford Park, Manchester, 17, are now available in self-spraying cans.

The dye-penetrant method of non-destructive testing has been developed for use where the absence of an electrical supply or suitably shaded area prevents the employment of electromagnetic or fluorescent techniques. Spraying the dye penetrant inks from pressurised cans is claimed to be much more economical and efficient than application by brushing.

By depressing a lever on the top of the can, the flaw-detection material is ejected in a fine spray which can be accurately directed on to the component under test. Surface faults are revealed quickly and positively as brightly coloured lines on a smooth matt-white background.

Portable test kits are now available. Each kit contains two self-spraying pressurised cans, one of dye penetrant ink and one of Devmor liquid developer. There is a choice of two types of ink —Verimor or Pentramor—which differ only in the method of removing surplus material. Distinctive colour schemes prevent confusion between cans.

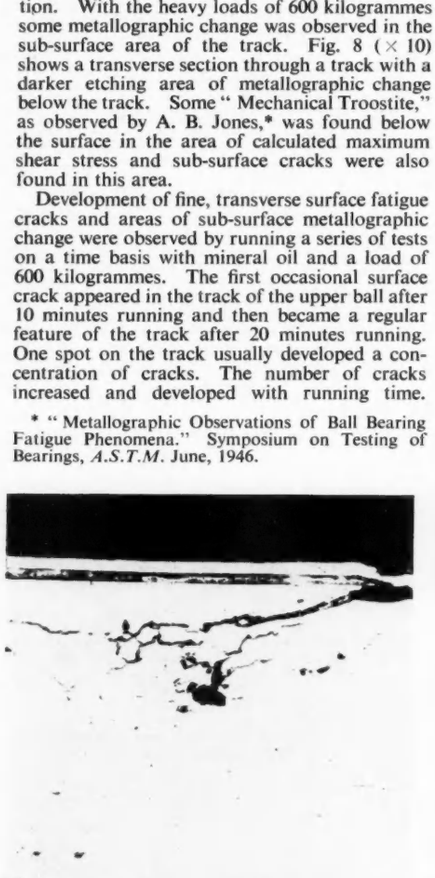

Fig. 11 Sub-surface cracks spreading from a pit (× 100).

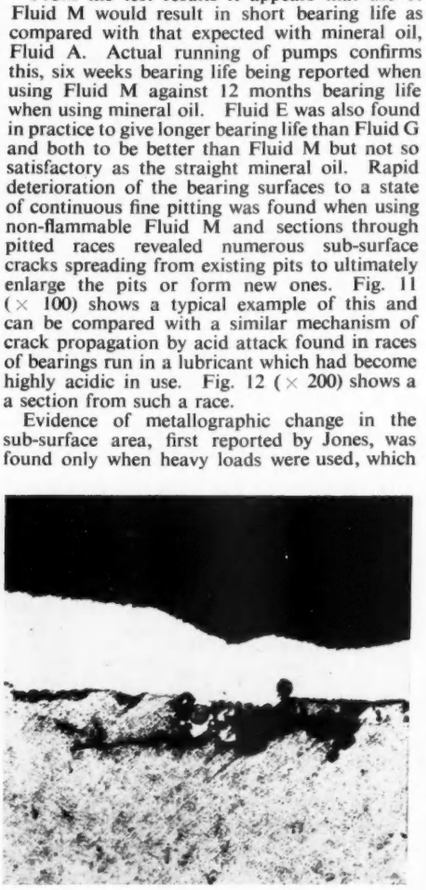

Fig. 12 Crack propagation by acid attack. Etched Nital (× 200).

ELECTRICAL EQUIPMENT OF AIRCRAFT

PRESENT POSITION AND FUTURE TRENDS

The main object of the Convention on the "Electrical Equipment of Aircraft," which was held recently at the Institution of Electrical Engineers, was to record the developments that have occurred in this country during recent years, about which very little has been publicised. It was also hoped to stimulate interest in the special design problems of electrical systems in aircraft and to provide an opportunity for manufacturers, constructors and operators to meet on common ground. During the Convention some 20 papers were presented and discussed under the general headings of "Electricity in Aircraft"; "Aircraft Electrical Systems"; "Machine and System Equipment"; and "Installation and Maintenance." Certain of these papers are reported below.

POWER SUPPLY SYSTEMS

In a paper on "Electrical Equipment in Aircraft," Mr. S. F. Follett said that the first supply systems, which came into use between the wars, were modelled on those of the motor car and consisted of a six-cell lead-acid battery with a nominal voltage of 12. For the stringent conditions of aircraft operation higher standards were, however, required and 500 watt generators, driven by small airscrews and mounted in the slip stream were installed.

Engine-driven generators with battery compounding were introduced in 1934, while the next major advance was the carbon-pile voltage regulator which was now almost exclusively used both in this country and in the United States. During the 1939-45 war the nominal direct-current voltage was raised to 24 and alternating-current supplies were provided for the radio equipment, either from engine-driven alternators, dual alternating direct-current generators with variable frequency and constant voltage or inverters driven from the direct-current supply.

Intensive development also took place in the components, including lighter accumulators, cables suitable for work under stringent conditions, and prefabricated wiring systems. The constant exposure of aircraft to the weather all over the world led to the use of waterproof and "tropicalised" equipment. The phenomenon of rapid carbon-brush wear, which was due to the high altitudes reached by reconnaissance aircraft, was also investigated.

At the conclusion of the war the total connected load of a four-engined Lancaster bomber was about 6·5 kW, including the radar and radio equipment. The lighting installation included recognition, identification and warning lamps, while motors were provided for starting and for driving the fuel, airscrew feathering and de-icing pumps. Supplies were also provided for heated clothing and bomb-gear operation, as well as for certain instruments and a number of minor requirements.

LOAD DISTRIBUTION

In modern aircraft, electricity was being increasingly used for various purposes so that on a typical bomber the estimated average load on the 112 volt busbars was nearly 40 kW, of which 11·2 kW was due to the flying control motors, 9·2 kW to the rotary transformers for the 28 volt direct-current supply, 8·3 kW for the inverters for the radar equipment and 5·2 kW for the fuel pumps. Electricity, in fact, was now employed for purposes which were essential not only to the aircraft's role as a weapon or as a means of transport, but for such uses as flying controls where continuity of supply was essential to safety.

The electrical equipment must therefore conform to the highest standards of engineering practice and its design might be considered under the headings of climatic conditions, acceleration and vibration. It was also obvious that the equipment must be of the minimum possible weight, while the reduction in its volume, especially in military aircraft, was becoming increasingly important. The risk of fire, the use and maintenance of the equipment by semi-skilled operators and reliability were other matters which had to be taken into consideration, as had the interference by other electrical equipment with the radio apparatus and magnetic compasses.

Dealing with the effects of trends in aircraft operation on the design of electrical equipment, Mr. Follett pointed out that increases in speed and altitude would lead to increasingly difficult operating conditions. Kinetic heating due to high speeds would require a new approach to the design of the generating equipment, since cooling by air-blast would no longer be possible; and, in order to economise in refrigeration all the electrical equipment would have to work at higher temperatures.

It was particularly important that the equipment should have the minimum weight and volume, since apart from financial considerations heavier airframes would be necessary. Improved reliability, both of components and complete systems, was required to obtain which and to remove faults before flight trials were undertaken, more testing under simulated operational conditions was suggested. Methods of driving generators by means other than the main engines were likely to be adopted, in order to provide power in case of engine failure. Some form of auxiliary gas turbo-alternator was probable in large aircraft.

FUTURE

Future trends were also considered in a paper by Dr. D. C. Flack, who pointed out that on present-day aircraft and those of the next few years two systems of generation would be essential: direct current at 28 volts and alternating current with a constant frequency of 400 cycles at 200 or 115 volts. If a single system of generation were employed secondary power would have to be supplied by converters. There would also be certain loads which required peculiar voltages and it was economical to provide individual equipment for these. Conversion from direct to alternating current and from direct to direct current at another voltage would be by motor-generators; but from alternating to direct current it could be achieved by rectifiers. The weight of the equipment for converting direct to alternating current or direct current to direct current was 40 lb. per kW and 47 lb. per kW, respectively, the efficiencies being 50 and 55 per cent. That for converting constant frequency alternating current to direct current would weigh 10 lb. per kW and for variable-frequency alternating current to direct current 15 lb. per kW, the efficiency in both cases being 90 per cent.

The choice of generation system depended primarily on the weight of each major group of utilisation equipment. Only fuel pumps and fans required continuously rated motors and alternating-current units were considerably lighter than direct-current for this purpose. Direct-current motors, however, were better than alternating-current for short-time ratings and their associated relays were also lighter. Either system could be used for the de-icing and galley equipment, the choice having little effect on the weight. The same applied to the lighting, although the robustness and efficiency were greater at low voltages.

Over one-third of the demand of the radio and radar equipment was for valve heaters and could usually be supplied by alternating current. High-frequency aerial power was provided by motor-generators or by transformers and rectifiers.

Most of the electrical instruments formed part of a telemetering system. Alternating current types were the more robust, but usually a little heavier. The overall weight was, however, small and the difference negligible. Both took very little power.

The reliability of servo-control systems for gas de-icing, air conditioning, propellers and the flying controls which were supplied by alternating current with transductor control was higher than that of direct-current systems. The demand was smaller than those of the heating and power loads.

WEIGHTS OF CABLES

Cables usually constituted the largest single item of weight in an aircraft electrical system, amounting to about one third of the total on a large machine. The standard cable used in this country was of the Pren type which could be operated at a current density of 7,000 amperes per sq. in., thus giving a considerable advantage in weight over other types, but resulting in a high voltage drop. Cable limitations had a profound effect on the system of supply and, where small powers were transmitted by alternating current, cable weights were considerably higher than those for direct current.

Dealing with the electrical installation of a civil transport aircraft with an all-up weight of 150,000 to 200,000 lb., the author pointed out that with a total alternating current demand of 90 kVA, a direct current demand of 12 kW, and an average load on an eight-hour flight only two types of generation need be considered: constant-frequency generation based on hydro-mechanical drives with direct-current conversion and variable frequency main generation and direct-current conversion plus a small amount of constant-frequency generation. The weights of the three constant-speed alternators necessary were similar, but an arrangement with four 35 kVA constant-speed sets and four 4 kW static transformer-rectifier units weighing 850 lb. appeared to be the most reasonable. The weight could be reduced by employing three 5½ kW units, while future rectifier developments would have the same result.

GROUND LOADS

Ground load requirements were increasing and this would have a profound effect on the overall design of an aircraft system. In fact, a modern civil aircraft could not be made ready for flight in the normal way without some form of external ground supply. The natural trend for this purpose was towards an auxiliary power unit, consisting of a self-contained gas turbine-alternator. This would only slightly increase the weight. Such units were necessary if the "take-up" was limited by engine power. An important limitation of the auxiliary power unit itself was, however, that the output of a small gas turbine decreased with the altitude. A combination of an auxiliary power unit and a "bleed and burn" turbine might therefore be necessary.

The total weight of the electrical equipment on a civil transport aircraft of the type considered in the paper was 6,900 lb. of which 2,805 lb. was accounted for by the cables and switches of the distribution system. These items therefore required the closest attention when considering future developments. Lighter cabling might be obtained by using higher current-carrying capacity, which could be achieved by the employment of insulants working at higher temperatures. Higher voltage drops would also permit some saving in cable weight, but would necessitate larger generators and increased fuel consumption, so that there would be no overall saving. The utilisation equipment, too, would have to be designed to work over a wider voltage range.

Most of the cables would, however, be carrying low-voltage direct current, and lower current densities should therefore be considered, as this would result in lower voltage drops and allow of lighter insulating materials operating at lower temperatures to be chosen. This might lead to a large saving in weight, particularly in the smallest sizes of cable. Nevertheless, this

would only alleviate the problem; and an increase in working voltage was essential since the resulting decrease in the diameter of the smaller cables would enhance the argument for lighter insulating material. Conductor materials such as cadmium-copper, the tensile strength of which was about twice that of annealed copper, should also be investigated.

The major factors, which influenced the design of an aircraft electrical system, were those associated with high ambient temperatures, due to increased speeds, and with low ambient pressure resulting from higher altitudes. Brushless alternators, probably driven by turbines which did not involve cooling problems, would certainly be developed. Power rectifiers might well be of the silicon type. Cables again constituted a controlling factor in high temperatures and, since voltage variation was a controlling parameter in the design of utilisation equipment, especially that required to operate over a wide temperature range, the conductor cross section must be increased on all except constant-load circuits.

COOLING ELECTRICAL EQUIPMENT

The cooling of electrical equipment imposed drag on aircraft and gave rise to a fuel-weight penalty. The air-cooling arrangements must be designed to meet the worst flying conditions; that is the lowest speed and highest temperature at a particular altitude. At other speeds, ambient temperatures and altitudes the equipment would impose an unnecessary drag. With the increasing requirements in quantity of air and higher speeds this might become serious and some form of automatic air-flow control might be justified.

There were a number of other fields in which development might be urged. These included the investigation of a constant-frequency drive which might be heavier, but should show higher efficiency, lower capital cost and greater reliability. The development of voltage regulating devices should be pushed forward. The adoption of higher speeds, and therefore higher generator frequencies, would mean smaller machine frame sizes and a reduction in weight.

Increase in frequency would, however, lead to an increased voltage drop on alternating current circuits, owing to skin and proximity effects. The reactance also increased with the frequency and was dependent on the relative positions of the cables. To use 800 cycles would mean that considerably more copper would have to be carried and this would more than offset any saving in the weight of machinery and equipment.

Mr. C. S. Hudson reviewed the methods of cooling electrical equipment and machines at present used on aircraft. Natural cooling, comprising radiation and convection, was much used, but where a greater reduction in temperature was required forced convective air cooling must be employed, the air being circulated either by a fan or by blast air from an external intake.

Assuming a hot-spot temperature of 200 deg.C. cooling by blast air became inadequate at speeds in excess of about 1,000 m.p.h., owing to kinetic heating, and at altitudes in excess of about 60,000 ft., owing to reduction of mass flow. The first step in the direction of more effective cooling was to restrict the blast cooling to a final heat interchanger or radiator, and to employ a local circuit between the equipment to be cooled and the heat interchanger. This would enable air at a constant pressure, a liquid coolant or a vaporisable liquid to be used as coolants.

By using air at a constant pressure as the coolant in the local circuit the drawback of a reduction in the heat-transfer coefficient with the altitude would be avoided in the generator. By raising the pressure above atmospheric an even greater heat-transfer coefficient could be obtained, but this would have to be weighed against greater windage loss due to the increased density of the air. This method of cooling had the advantage that existing designs of machine could be readily adapted, the main change necessary being the provision of bearing seals.

As regards liquid cooling certain auxiliary equipment such as a storage tank, air-circulating pump and heat interchanger would be required. The main difficulty in the application of this system was the cooling of the armatures of rotating machines which required rotating seals at the ends of the shaft. Research indicated that this problem was capable of solution for conventional speeds and for fluids of the kerosine type, but little was known about seal behaviour at the speed of 24,000 r.p.m. encountered in a 400 cycle alternator.

EVAPORATIVE COOLING

Evaporative cooling employed a liquid with a high latent heat of evaporation as the coolant. This liquid was allowed to boil on the surfaces from which the heat had to be taken, the vapour being then removed and condensed. Use was made of both the specific and latent heats of the coolant, and hence only a low flow-rate was necessary to remove the heat to be dissipated. The improvement over liquid cooling expressed as heat removal per unit mass of coolant might be between 10 and 20 times. As the temperature of the surface was increased beyond the boiling point of the liquid coolant used the heat-transfer coefficient increased and attained a maximum when the temperature difference reached a critical value (for water about 20 deg. C.). As the temperature was increased beyond this critical value the heat-transfer coefficient fell, and care was necessary to see that it was not exceeded, since if a hot spot formed there was a tendency for catastrophic runaway of temperature.

It might be possible to use generators of fairly conventional design with evaporative cooling, the coolant being sprayed into the machine, allowed to boil on the hot surfaces and the vapour removed by a suction pump. The problems which remained to be solved were the protection of the windings and metal parts of the generator, the control of the fluid circulation, the avoidance of hot spots and the choice of a coolant with the requisite thermal properties which would be compatible with the various materials used in the construction of the machine and also would not freeze.

For a hot-spot temperature of 200 deg. C. direct cooling was not effective at speeds above 1,400 m.p.h. It was also ineffective at altitudes above 70,000 ft., although some improvement might be achieved if a local cooling circuit were used for removing heat from the generator, and the final transfer to the outside air took place in a radiator with good aerodynamic properties. With this arrangement the local circuit would be unaffected by ambient conditions and would operate with constant temperature differences. The small drops at the radiator would still be dependent on mass flow and hence on speed and altitude, but the mass flow and surface area could be made so large that the wall drops remained small. This type of cooling gave substantially improved performance at altitudes above 40,000 ft., but if speeds in excess of about 1,200 m.p.h. were required some means of surmounting the thermal barrier was needed.

SURMOUNTING THE THERMAL BARRIER

To surmount the thermal barrier the choice lay between expendable coolants and heat pumps. In any cooling system there must be a heat sink to which the heat extracted from the equipment was rejected. In aircraft the outer air was generally employed as a heat sink, but at speeds in excess of 1,200 m.p.h. the heat sink temperature was greater than that of the coolant. Cooling therefore involved the extraction of heat at the lower temperature of the equipment and its rejection to the atmosphere at the higher temperature of the skin of the aircraft.

One of the well-known refrigerator cycles could be used for pumping the heat from the lower to the higher temperature. To keep the expenditure of work to a minimum the temperature difference must be kept small and the cooling system must therefore operate with a mean coolant temperature as close to the maximum operating temperature of the equipment as possible. The heat at the higher temperature was transmitted to the outside air in some form of heat interchanger and the air cooling of this interchanger should be at the lowest possible temperature. This meant that the air should be taken from the air inlet or from a very early stage of the compressor. The inlet and radiator needed careful aerodynamic design to minimise drag losses.

In some cases, such as short-duration aircraft, it might be simpler to surmount the thermal barrier by using an evaporative coolant to extract heat from the equipment to be used and rejecting it after use. Where the fuel could not be employed for this purpose the coolant should be a substance with the largest thermal capacity for a given mass.

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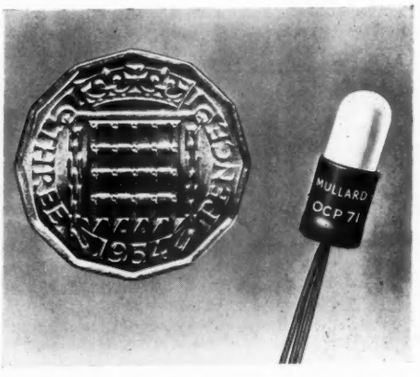
PHOTO-TRANSISTOR

Sensitive Light-Operated Device

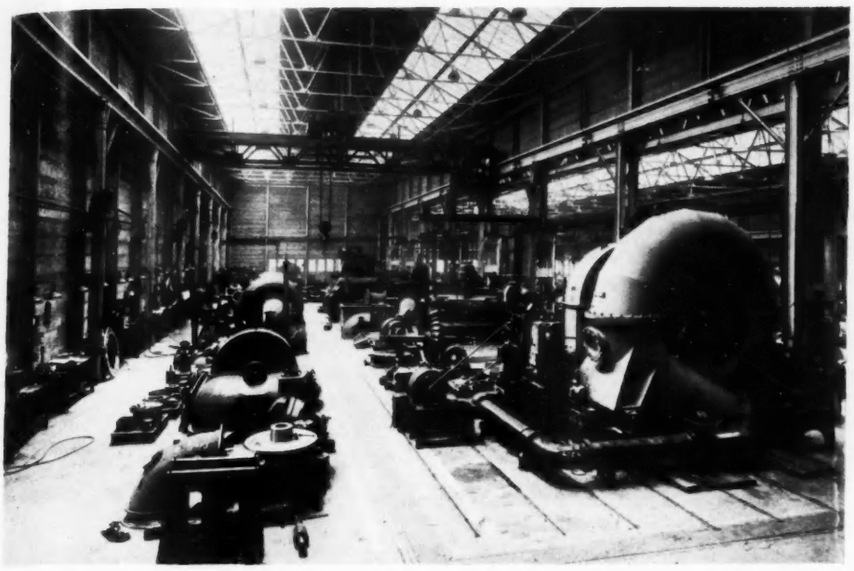
A new photo-electric device, which we understand is the first of its type to be produced in this country, has been introduced recently by Mullard Limited. It is a germanium photo-transistor, known as type OCP 71, and is similar in form to a conventional low-power junction transistor but is sufficiently sensitive to operate a normal type of relay directly. It has the advantage of small size and, as is the case with other transistors, can operate at low voltages but is not suitable for use at temperatures above about 40 deg. C.

The photo-transistor is provided with three connections but for most applications the base is left floating so that only two of them are required. The circuits in which it may be employed are extremely simple; it can, in fact, be merely connected in series with the relay coil and a battery of 12 to 18 volts. If, however, it is required to operate the photo-transistor over a wide range of temperatures the base electrode may be supplied with a small positive compensating bias in order to maintain the " dark " current at a low level. Normally the dark current does not exceed 300 microamperes at 25 deg. C., whereas the light current can be of the order of 5 to 10 milliamperes. The response is peaked in the infra-red part of the spectrum but continues into the visible-light region.

The maximum dimensions of the OCP 71, shown below, are 5·9 mm. in diameter and 15 mm. in length, which can be most easily realised by comparing it with a threepenny piece as in the accompanying illustration. Its small size makes it particularly suitable for tape and punched-card reading. It is, however, suitable for most industrial control applications such as photo-electric counters, speed measurement, liquid-level controls, edge detection in paper-making and textile machines and for belting. A particularly important characteristic in some of these applications is that the optical cut-off frequency, that is the maximum frequency of response when the light source is chopped or otherwise interrupted, is in the region of three kilocyles per second.



Mullard OCP 71 photo-transistor, compared in size to a threepenny piece.



New shops and new equipment have been provided since the war at the works of Gilbert Gilkes and Gordon, Limited. This view shows the turbine erection bay.

WATER TURBINE MANUFACTURE 1856–1956

THE CENTENARY OF GILBERT GILKES AND GORDON, LIMITED, KENDAL

In 1856, two brothers, Henry and William Williamson, moved an existing business into Kendal, Westmorland, from a village nearby, and started a little foundry and engineering shop to cater for local needs. Their works, called Canal Iron Works (as they still are), from the fact that they occupied two disused warehouses at the Kendal end of the Lancaster Canal, were like most other little country shops of the time. They had no special product. Small steam engines, saw benches, agricultural equipment, bobbin machinery and anything else for which the firm could get an order passed through the Canal Iron Works.

In the first year of existence of the new works, however, Williamson Brothers took an order for a machine which was to be the first of many, and marked the beginning of a world-wide business. The order was for a 5 h.p. vortex water turbine, to the design of Professor James Thomson, brother of Lord Kelvin. This machine, which operated under a head of 31 ft., was installed at a farm near Kendal, for driving agricultural machinery, and it remains in working order to-day, being used from time to time. History does not record how the original contact was made between Professor Thomson and Williamson Brothers, but it had a far-reaching effect on the fortunes of the firm. Professor Thomson granted a manufacturing licence to the Kendal firm, and they began to specialise in the production of vortex water turbines, the business being extended beyond the purely local connection with which it had started. In the first 25 years of partnership at Kendal the Williamsons made 440 turbines, their customers ranging as far away as Australia.

GILBERT GILKES

In 1881, the Williamsons decided to retire, and sold their business to Gilbert Gilkes, M.I.C.E., of Middlesbrough, who gave his own name to the concern, calling it Gilbert Gilkes and Company and adding "Formerly Williamson Brothers"; this latter was soon dropped as the name of Gilkes became better known. Under Gilkes's proprietorship and personal management the range of products was extended, the first acquisition of another water-power business, that of Mr. C. L. Hett, of Brigg, took place, and the first edition of the firm's handbook "On the Development of Water Power" was issued. This handbook, which appeared in 1896, was written by Gilkes himself. It has been revised as necessary and re-published every few years since its first appearance.

Gilkes took into the business in 1894, his nephew Mr. Norman F. Wilson, J.P., A.M.I.C.E., who later became chairman of the Company, and whose son, Mr. Paul N. Wilson, D.S.C., M.A., M.I.C.E., M.I.Mech.E., is the present chairman. Mr. Paul Wilson has three fellow-directors, Mr. Eric Crewdson, M.C., J.P., B.Sc., A.M.I.C.E., D.L., a great-nephew of Gilbert Gilkes, Mr. Peter E. F. Crewdson, elder son of Mr. Eric Crewdson, and Mr. R. Lyon Wyllie, J.P., F.C.A.

The firm took its present title of Gilbert Gilkes and Gordon, Limited, in 1928, when the business of James Gordon and Company, Limited, of London, was purchased. Subsequent purchases brought to Kendal the businesses of Carrick and Ritchie of Edinburgh, and Gunther and Sons of Oldham.

TECHNICAL DEVELOPMENTS

All the turbines made by Williamson Brothers were Thomson vortex wheels, most of the early ones being for driving machinery of various types. Electric power generation, however, figured quite early in the firm's history, and the pioneer British underground electric haulage at Greenside Lead Mine, Westmorland, was powered by a Kendal water turbine made in 1893. Pelton wheels were made from 1894 onwards, and a number of very large ones have been produced, including two of 21 ft. diameter which were installed in South Wales in 1903. Turbines were also designed for transport in the less-accessible parts of the world Four machines sent to Peru in 1906, for example, had to be broken down for transport on mule-back. Other machines were made to comply with similar requirements. This problem has not arisen much in recent years, because of the world-wide improvements which have taken place in transport methods, but it is of interest to record that in 1951 and 1952, the firm supplied three 125 kW low-fall hydro-electric sets for use in Lhasa, Tibet, and a weight restriction of one ton was imposed on individual components.

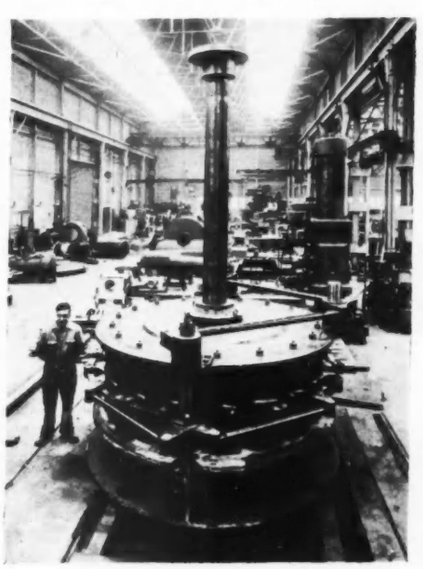
THE TURGO IMPULSE WHEEL

The invention of the Turgo impulse wheel by Mr. Eric Crewdson in 1919 was an outstanding event in the history of the business. This machine is a free-jet impulse wheel in which the jet enters the runner from the side at an angle and is discharged at the opposite side. It has the great advantage that its specific speed is substantially higher than that of a Pelton wheel, and with the original design a ratio of 5·6 to 1 was obtained between the mean diameter of the runner and the diameter of the jet. At that time it was unusual to operate a Pelton wheel with a ratio lower than 10 to 1. Subsequent developments made it possible, by 1936, to design a wheel giving a high efficiency with the runner-jet ratio as low as 4·4 to 1, and a specific speed of about 11·5 r.p.m. The Turgo impulse wheel virtually eliminated the need for building multi-jet Pelton wheels as its speed was higher than that of the normal two-jet Pelton, the machine itself being smaller and much simpler.

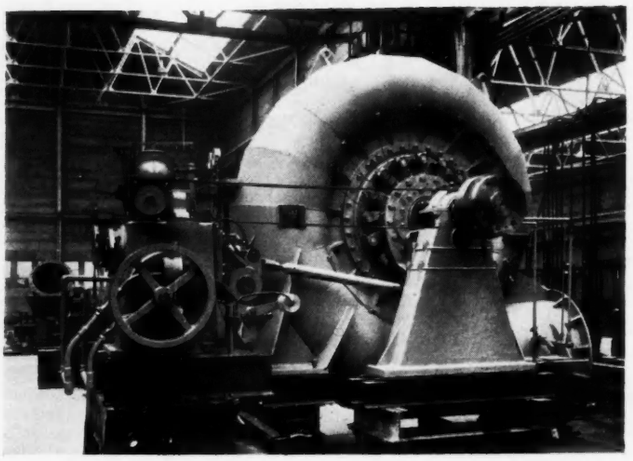
There have also been numerous developments in the methods of construction used for water turbines. Gilkes were among the first manufacturers to cast Pelton wheels in one piece, their first integral-bucket Pelton wheel being made in 1928. There have been corrosion problems too, especially in the case of power-recovery turbines used in chemical works with high-pressure process water. Gases in solution in the water have caused severe corrosion, and in one instance it has been overcome by the use of drop-forged stainless steel buckets.

SPEED GOVERNING

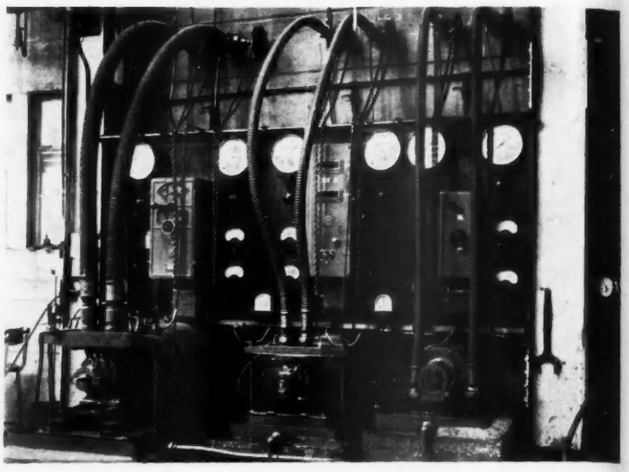
Originally all turbines were controlled by hand gear, some having nothing more than a valve at the inlet. The advent of electrical drives made governors essential, and the first ones to be produced at Kendal appeared just before 1900. Both mechanical and hydraulic governors were built, but difficulties persisted until 1907, when the first of the Gilkes oil-pressure type governors was made. To-day, the governors in production include the oil-pressure, electric brake and Giljet types. The oil-pressure governor consists essentially of a speed-sensitive pendulum driven from the turbine shaft and operating a distribu-



A typical larger product, shown under erection, is this 1,100 h.p. open-type Francis turbine, supplied for use in British Guiana.



This spiral-cased Francis turbine equipped with an oil-pressure governor, develops 1,400 h.p., and is installed in New Zealand.



Among the smaller products of the Kendal works is the " GGG " self-priming pump. The production testing rig for this pump is shown here.

tion valve which controls the flow of oil to a servo-motor cylinder. A built-in gear-pump provides oil under pressure for the servo system. A rocking shaft is operated by the servo motor, and this shaft is connected to the turbine guide vanes or deflector gear.

The electric brake is an eddy-current device which maintains a constant load on the turbine, the brake load being varied automatically so that when combined with the generator load the total figure is constant. The energy absorbed by the brake is dissipated by water cooling. This device, which was designed by Mr. Eric Crewdson in 1925, has proved very successful for such installations as small domestic units operating with a direct-current supply, and for turbines using compensation water from dams, where a fixed volume of water has to be passed through the machine irrespective of the electrical load.

The latest of the governors in the range is the Giljet, patented since the war by Mr. Paul N. Wilson. This governor also works on the power-absorption principle, but it uses an impulse-type hydraulic brake to absorb the power when the turbine speed rises. In practice suitably-designed buckets are formed in the rim of a totally-shrouded flywheel, and a jet of water from the turbine casing is allowed to impinge on these buckets, which rotate towards the jet; a retarding torque equal to the full-load torque of the turbine can be built up almost instantaneously. The volume of water passing through the jet is relatively small, and this artificial load can be imposed so quickly that the speed-rise of the turbine and the pressure-rise in the penstock can be limited to a very low figure. The jet is then closed very slowly, giving the effect of a gradual reduction in load on the turbine. The system has been evolved for governing Francis turbines operating with very long penstocks where it is often impossible, and always expensive, to build a surge tower.

PUMPS

Pumps have been made at the Kendal works since the early days of the Williamsons. In 1933, Mr. Eric Crewdson developed the " GGG " self-priming pump which is of the water-ring or side-channel type. It is highly efficient with a high-head characteristic at relatively low speed, and primes very rapidly even after it has been idle for long periods. The pump is made in single and two-stage patterns, with various forms of drive for industrial, marine, agricultural, and other uses. A specialised application is its use in the Giljector bilge and wash-down system designed for small engine-propelled boats.

A " GGG " pump is belt-driven from the engine, and draws sea water, which can be used through a hose for washing down or fed to an injector which draws the water from the boat's bilge. Any solid matter which accumulates in the bilge passes easily through the ejector, and cannot choke the pump, which it does not enter.

RESEARCH AND DEVELOPMENT

A water turbine testing tank, which was the first equipment of its kind to be built by a turbine manufacturer in the United Kingdom, was installed at Kendal in 1934, and it has been in constant use ever since. Turbines for test are usually erected on top of the tank, and water is supplied by a centrifugal or propeller pump of the appropriate size. Water flow is measured by means of a V or rectangular weir and the horse-power output of the turbine is determined by means of a Prony brake.

Additions are now being made to the equipment. Two new tanks complete with measuring weirs have been sunk in the floor for testing pumps up to a maximum output of 2,000 gallons per minute, and there is also a bore hole 300 ft. deep, lined to 11 in. diameter and plugged at the bottom. This can be used for testing bore-hole pumps by filling it with water to the required depth and re-circulating the water. A modern research laboratory adjoins and overlooks the testing department, and beneath it is a demonstration room with working examples of products including a 5 kW hydro-electric unit, pumps driven by various prime movers.

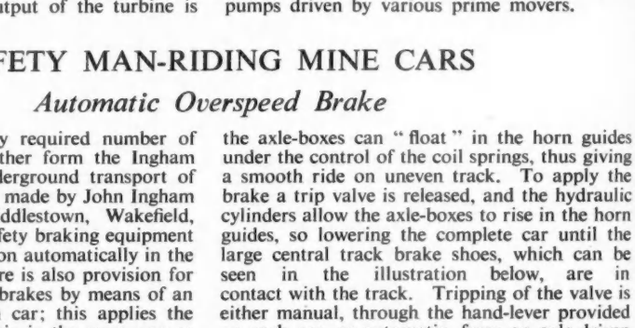
SAFETY MAN-RIDING MINE CARS

Automatic Overspeed Brake

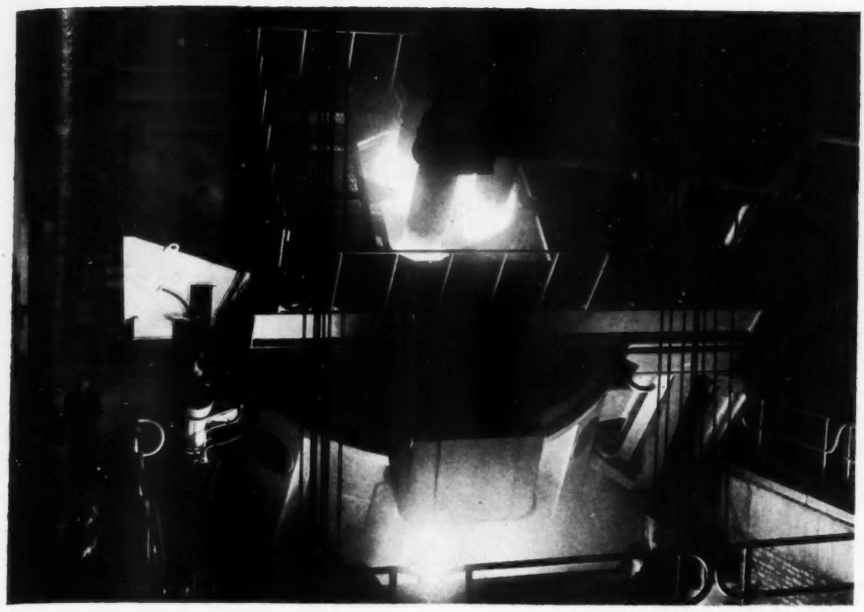
One master car and any required number of brake cars coupled together form the Ingham man-riding train for underground transport of personnel. The vehicles, made by John Ingham and Sons, Limited, Middlestown, Wakefield, Yorkshire, incorporate safety braking equipment which comes into operation automatically in the event of overspeed. There is also provision for manual operation of the brakes by means of an emergency lever on each car; this applies the brakes throughout the train in the same way as the automatic overspeed control, and in either case the train is brought to rest smoothly and progressively.

Each vehicle is carried on four wheels, the axle boxes of which slide in horn guides on the chassis. Coupled to the axle-boxes through bell-crank levers are horizontal hydraulic cylinders with coil-spring dampers. Under normal running conditions the cylinder rams are extended, and the axle-boxes can " float " in the horn guides under the control of the coil springs, thus giving a smooth ride on uneven track. To apply the brake a trip valve is released, and the hydraulic cylinders allow the axle-boxes to rise in the horn guides, so lowering the complete car until the large central track brake shoes, which can be seen in the illustration below, are in contact with the track. Tripping of the valve is either manual, through the hand-lever provided on each car, or automatic, from an axle-driven centrifugal governor on the master car.

The brakes are coupled to operate throughout the train, and the rate of application is pre-set to ensure maximum deceleration consistent with safety to the passengers. Fabric linings are fitted to the brake shoes, and re-lining is a simple matter. The cars can be operated by endless rope or direct haulage, on straight or curved tracks, and on steep gradients.



Any number of cars can be coupled to a master car to form the Ingham man-riding train, which has automatic overspeed braking.



Tapping a 60 ton electric arc furnace at the works of Samuel Fox and Company Ltd.

Book Reviews

SYMPOSIUM ON STEEL CASTINGS

The Casting of Steel. Edited by W. C. NEWELL. *Pergamon Press, Limited, 4-5 Fitzroy-square, London, S.W.1.* (105*s.*)

One of the dangers of specialisation, which is inseparable from modern industry, is that it is possible for an individual to become so involved in a particular aspect of his subject that he has no proper appreciation of the whole. The complexity of industry is such that no human mind can assimilate more than a small part of the total knowledge available, and specialisation in limited fields is unavoidable. With this specialisation, there comes a need for co-operation, and it is here that the dangers of too narrow an outlook are greatest. It is all too easy to scrap a job because something is done or omitted at one stage which will undo what has been done before, or will provide a basis for failure in what follows. A reasonable knowledge of the other links in the chain can do much to prevent such occurrences, and it can often also help in other ways.

It is on this basis that the present book is arranged. Dr. Newell has co-ordinated the work of 15 specialists to produce a book giving a balanced overall picture of the production of steel castings. Each of the 13 chapters is self-contained, and they are arranged in a logical sequence leading from the properties of the liquid metal and the mechanism of solidification, through such questions as melting, refractories, pattern making, moulding, casting and heat treatment to the testing of finished castings. It is not, however, necessary for the book to be read through from the beginning in the normal way.

The self-contained nature of the chapters makes it possible for readers who are more interested in, or familiar with, the practical aspects of the subject, to start in the middle of the book, and look back to the earlier chapters for references to basic principles. Conversely, those whose training or interests are academic will find themselves on more familiar ground if they start with the earlier chapters, which are of a theoretical nature; they can work on to the less-familiar practical considerations of moulding and casting. Whichever way the reader decides, as a result of his inclination or training, to study the book, the result is the same. Reading the whole book will provide a good overall understanding of the production of steel castings, including the more modern developments in centrifugal and investment casting as well as in non-destructive testing.

The chapters are profusely illustrated, and a useful guide to further study is provided by the bibliographical references which are grouped together at the ends of the chapters. An adequate index enables quick reference to be made to particular items or aspects of the subject irrespective of the arrangement of the chapters.

To cover adequately the large range of subjects connected with the production of steel castings and to keep the book within a reasonable compass are two opposite requirements which it is difficult to reconcile. The editor recognises that there are gaps, as is inevitable in the circumstances, but in his aim of giving a balanced view of the whole subject, he has succeeded well. Any one of the many specialists concerned with the production of steel castings—the metallurgists, refractory and furnace engineers, pattern-makers, foundry personnel, test house and laboratory staffs, will see, from a study of this book, his own activities and those of the other groups placed clearly in their proper perspective. Similarly, engineers who have to specify or use steel castings, will find the book of value, as will those whose job it is to design and manufacture equipment for the foundry.

It would be easy to find minor points for criticism, as indeed it always is. The title of the book, for example, might be said to be slightly misleading. Very large quantities of steel are cast into ingots, a process which is of considerable importance if the finished product is to be satisfactory, but it is not one which is dealt with, or intended to be dealt with, in this book, though the title might tend to indicate that it is. Practically all the illustrations are good, but there are one or two which are mainly of pictorial interest and do not help to explain the text or supplement it. Such points, however, are of minor importance, and do not detract from the value of the book, which does all that its editor and contributors set out to do.

LIBERATION FROM DRUDGERY

Automation: A Challenge to Trade Unions and Industry. *Association of Supervisory Staffs Executives and Technicians, Sutton House, 2-4 Homerton High-street, London, E.9.* (1*s.*)

Apart from the outcry arising from the crisis in the motor-car industry in recent weeks, the attitude of trade unions in this country towards the over-dramatised possibilities of "Automation" has been cautious and pragmatic, contrasting sharply with that of the American unions as illustrated by the evidence given before the Congressional Committee which examined the subject. This pamphlet is typical of that attitude and is, in fact, one of the best short popular statements that have appeared. It recognises that the greatest change that is taking place is in the use of electronic devices which are capable of memorising and discriminating between data, and that this has great possibilities for the liberation of man from dreary menial tasks: "Machines can now be made sufficiently like men to avoid the danger of men needing to become machines."

The authors recognise that there need be no danger of general unemployment as long as Government policy ensures that there is a high enough level of consuming power, plus capital investment at home and abroad to absorb the output of increasing productivity; but they take too little account of the problems of a country dependent for the greater part of its food and raw materials on a high level of exports.

From the trade-union point of view one of the most serious problems to be faced is the change of skills that are going to be needed—for workmen, supervisors and management. There is also the problem that the productivity of labour in different industries may differ even more sharply than at present and a "new poor" be created—those not working in industries able to use the new techniques. Will this make necessary a national wages policy to which so far most trade unions have been opposed? This may not be necessary, for even without such a policy economic forces would presumably settle this problem in time, for the wages of the unpleasant and less mechanised industries would have to rise to attract labour and so would the prices of their products. There may, however, develop sharp sociological distinctions which could be economically and socially harmful to the community. One cheerful thing the authors of this pamphlet suggest is that, as wealth increases and is more widely distributed so that need becomes a more distant danger, there may be an extension of artistic and handicraft work. In the age of automation, the aesthetic may become economic.

TEACHING THERMODYNAMICS

Technology of Heat. By PROFESSOR H. WRIGHT BAKER. *Longmans, Green and Company, Limited, 6 Clifford-street, London, W.1.* (36*s.*)

Professor Wright Baker's *Technology of Heat* provides an interesting comparison between some of the methods of teaching thermodynamics and heat engines employed in this country, and the more rigorous American and Continental methods of approach. The books by Schmidt, Zemansky, Keenan, and Mooney are representative of the second school.

If Professor Wright Baker's book is to be judged in relation to the standards of these other books, then it is found that the chapters dealing with basic thermodynamics are inadequate. The statement of the first law of thermodynamics, "that heat and mechanical energy are mutually convertible," is not precise, for there is no mention of the qualification of the cyclic process $\left(\text{i.e., that } J\oint dQ = \oint dW\right)$ or that there are any limitations implied by the second law of thermodynamics. Such a statement of the first law

leads to a hazy distinction between heat and internal energy.

The statement of the second law is no more convincing—" any reversal of the principle . . . that any unaided physical reaction will take place in a manner which will tend to smooth out differences . . . forms the basis of the second law of thermodynamics." It follows that concepts of reversibility, definitions of the absolute temperature scale and entropy, must be doubtful if based on these foundations. The beauty of the logical developments from the second law (Keenan, Chapter VIII) is lost in this book.

There is no satisfactory distinction in *Technology of Heat* between the steady-flow energy equation and the Bernoulli equation. The author suggests that for a liquid flowing at constant temperature, the steady-flow energy equation reduces to the Bernoulli equation. The concept of reversible flow is not developed.

The statement that the entropy of the " system" increases in non-reversible cycles indicates that the author's definition of " system " is not conventional, and will be confusing to most students of thermodynamics. Further, the sentences " (1) Entropy is a condition of the state. This applies whether the specific heat is constant or variable but (2) if the specific heat varies, areas on the T, *s* chart do not represent heat quantities to a uniform scale " will add to the confusion. If entropy is a condition or property of the state of a system, there will be no internal change of entropy in a cycle, reversible or irreversible.

On the technological aspects of heat engines, the author is on safer ground, and the chapters on refrigeration, heat transfer, internal-combustion engines and gas turbines are good, but even here the influence of basic misconceptions is apparent. Can we not dispense with the idea of " heat liberated in combustion " by using a correct statement of the first law and a correct definition of internal energy ? In this way the variation of calorific values with temperature, not mentioned in this book, may be dealt with very simply. Morover, on reading a statement such as " mechanical friction will reappear as heat," many teachers will recall the remarks of Kaye and Wadleigh (*J. App. Mech.*, 1951) who said " the authors agree that the phrases ' gain in energy due to reheat ' and ' recovery of heat due to hydraulic losses ' are completely misleading and should never be used."

This book emphasises the difficulties of teaching thermodynamics. Is the teacher to be frank and to say that the preliminary ideas must be derived rigorously in a difficult lecture course ? Or is he to pass over these difficulties and produce a course of thermodynamics, which is satisfyingly algebraic, and in which

$$dQ = T\,ds = C_v\,dT + p\,dv$$

always, through reversibility or irreversibility ?

The answer may be that it depends on the calibre of the engineering student; but if engineering students are to be of the highest calibre, then the courses offered to them must form a sound intellectual discipline.

★ ★ ★

NEW BOOKS

Some of the books noticed here are selected for extended review in ENGINEERING.

Recommended Practice for Electrical Installations in Caravans. Second edition. *The Institution of Electrical Engineers, 2 Savoy-place, London, W.C.2.* (1*s.* 3*d.*)

Recommendations of the Wiring Regulations Committee of the Institution of Electrical Engineers for the connection of an electricity supply to trailer caravans connected to the mains; and methods of earthing. The provision of an earth-leakage circuit-breaker in every caravan is suggested, as is the text of a notice " Instructions for Electricity Supply," which should be fixed near the main switch.

Conditions of Contract and Insurance : A Practical Guide for Contractors. By GEORGE T. N. HAGART. *Witherby and Company, Limited, 15 Nicholas-lane, London, E.C.4.* (10*s.*)

This book is an attempt to explain in non-technical language and as simply as possible some of the problems which confront contractors and the way they can be met. It does not purport to be a legal discourse on the subject, and no detailed reference is made to legal cases. The book is divided into two parts: Part I dealing with considerations arising where no conditions of contract apply, and Part II with occasions where conditions of contract do apply. Included in Part II are: general conditions of contract for works of civil engineering construction ; I.Mech.E./I.E.E. model form of general conditions of contract; and general conditions of Government contracts for building and civil engineering works.

Electronic Engineering. By SAMUEL SEELY. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (8 dols.); *and McGraw-Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (60*s.*)

A detailed discussion of the electronic circuits which are important in such fields as radar, television, control and instrumentation and computers. Most of the text is devoted to analysis of circuit operation. The treatment, which is mainly based on American practice is largely mathematical.

Electric Generation: Steam Stations. Edited by BERNHARDT G. A. SKROTZKI. *McGraw-Hill Book Company, Incorporated, 330 West 42nd-street, New York 36, N.Y., U.S.A.* (8.50 dols.); and *McGraw Hill Publishing Company, Limited, 95 Farringdon-street, London, E.C.4.* (64*s.*)

This book describes the basic principles of the steam generating stations which provide most of the electrical energy in the United States. It covers fuel supply, boilers, turbines, condensers and feed-water systems, electrical generation and auxiliary drives. There are a number of contributors and it is written for the man who has had no engineering training.

The following reports may be obtained from the Librarian, College of Aeronautics, Cranfield, Bletchley, Buckinghamshire:—

A Review of Plastics for Use in the Aircraft Industry. By F. FAHY. Note No. 43. (5*s.*) This survey, which the Author does not claim to be comprehensive, is grouped into four main parts: 1. structural plastics, covering glass laminates, asbestos laminates and paper and cloth laminates; 2. thermoplastics covering polymethyl methacrylate, nylon and polytetrafluorethylene; 3. adhesives, covering Araldite and Redux; and 4. foamed plastics. It covers the mechanical properties and applications, but the electrical properties are not dealt with.

The Flexure-Torsion Flutter of Cambered Aerofoils in Cascade. By A. H. CRAVEN and I. DAVIDSON. Report No. 95. (5*s.*) This report contains the results of a series of tests on the flexure torsion flutter of cascades of aerofoils of 30 deg. and 45 deg. camber. The critical flutter speeds and frequencies in cascade are expressed as ratios of the values for the aerofoil in the isolated condition. The tests cover stagger angles between − 30 deg. and + 30 deg. and gap-chord ratios up to 1·5 at a Reynolds number of 1×10^5 based on aerofoil chord. It was found that the effect of camber was to increase the critical flutter speed ratio and to decrease the critical frequency ratio. The flutter characteristics also depended on the magnitude and sign of the stagger angle. Limited tip clearance was shown to reduce the flutter speed ratio but to have little effect on the critical flutter frequency ratio. Small angles of incidence were found to have negligible effect on the characteristics. It was noted that adjacent aerofoils were oscillating approximately 180 deg. out of phase.

A Framework for Compensating Rest Allowance. By R. M. BELBIN. Note No. 35. (5*s.*) This paper was written for a conference in Cambridge, in April, 1955, on individual efficiency in industry. The object was to consider the problem of compensating rest allowances, as applied by time-study engineers, in the light of scientific evidence. The author concludes that such allowances should cover: (*a*) fatigue associated with heavy work and heat strain; (*b*) sensory fatigue and (*c*) mental fatigue. In category (*a*) limiting allowances would be based on calorie expenditure and sweat loss, and a continuity allowance would be given where items of heavy work and work involving postural strain were closely grouped. In category (*b*) he proposes allowances in the case of visual fatigue based on viewing distance and in category (*c*) allowances based on the extent to which demands on attention and concentration are involved in repetitive work.

An Approximate Solution to the Swept Wing Root Constraint Problem. By D. HOWE. Report No. 98. (5*s.*) The structure considered in this report is a uniform rectangular single-cell box having closely spaced rigid ribs. An approximate allowance is made for the effect of boom area at spar-skin joints. The stress distribution in the skin is repeated by a polynomial in the chordwise ordinate, oblique coordinate notation being used. The final equations are derived by use of the theory of minimum strain energy. Comparison with experimental results has indicated that the theory gives a satisfactory estimation of the constraint effect and especially the influence of the spar boom.

On the Synthesis of 3-Terminal RC Networks. By K. M. ADAMS. Report No. 96. (5*s.*) This report is concerned with the synthesis of three-terminal RC networks according to three specified network functions. Some necessary conditions for physical realisation are derived from first principles by an algebraic method. The possibility of synthesis is shown to depend upon a certain inequality, but the weakest conditions required in order to satisfy it are not yet known.

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TRADE PUBLICATIONS

Copies of any of the following trade publications are obtainable from the addresses given, though distribution is sometimes restricted.

Beryllium Copper Dies. BERYLLIUM SMELTING CO., LTD., 36/38 Southampton-street, London, W.C.2. Beryllium copper can be cast with very close reproduction of detail and a good surface. It has high thermal conductivity, good corrosion resistance and high impact strength. Can be precipitation-hardened. Has an increasing application for the manufacture of plastic moulds and dies, light-alloy forging dies, forming and drawing dies for steel and titanium, and zinc casting dies. Damaged, worn or obsolete dies can be melted and re-cast. Illustrated leaflet with technical details of two beryllium copper alloys and examples of how the material can be used for each of the purposes mentioned above.

Forged Steel Valves. NEWMAN, HENDER & CO., LTD., Woodchester, Stroud, Gloucestershire. Forged steel valves with boxes up to 2 in. in diameter for service at pressures up to 3,000 lb. per sq. in. (cold) and temperatures up to 1,000 deg. F. Available in various alloys and as gate, plug or globe forms; also needle valves for metering and control, working up to 4,000 lb. per sq. in. at 450 deg. F. Vertical and horizontal check valves of ball or piston type. Illustrated 80-page catalogue.

Electric Grease Gun. HEADLAND ENGINEERING DEVELOPMENTS LTD., 164/168 Westminster Bridge-road, London, S.E.1. The " Kama " grease gun, operated by an electric vibrator housed in the centre. Effective pressure 7,400 to 8,200 lb. per sq. in., capacity 18 oz. of grease. Supplied with four adaptors for different types of nipple and a length of flexible hose for reaching awkward positions. Illustrated leaflet.

Platform Truck. YALE AND TOWNE MANUFACTURING CO., Wednesfield, Staffordshire. The " Warehouser " battery-driven rider-controlled platform truck of 2 tons capacity. Platform available in three widths, 19, 24 and 26 in. and five lengths, 36, 42, 48, 54 and 60 in. Lift 4 in. Steering through spur reduction gear giving an arc of over 200 deg. spring loaded dual castor wheels on platform. Illustrated leaflet.

Contact Materials. JOHNSON, MATTHEY & CO., LTD., 73 Hatton Garden, London, E.C.1. Data sheets showing the physical properties of the principal contact materials in general use and the forms in which they are available; the choice of contact materials for contactors and starters handling currents of 30 amperes and upwards; and of silvered-mica capacitor plates. Illustrated technical information.

Locomotives. VULCAN FOUNDRY LTD., Newton-le-Willows, Lancashire. This well-known locomotive building firm, founded in 1830, is now a member of the English Electric Group of Companies. Illustrated description of the works. Data sheets of typical steam, Diesel-mechanical, Diesel-electric and electric locomotives. Brief history of the company, etc. Comprehensive brochure of 124 pages.

Electrostatic Loudspeakers. H. J. LEAK & CO., LTD., Brumel-road, London, W.3. Balanced push-pull electrostatic loudspeaker with low harmonic and transient distortions. Light metallically coated plastic surface sustaining an electrostatic charge. Illustrated leaflets.

Electronic Apparatus. A. E. CAWKELL, Southall. Noise and vibration measuring equipment; continuously variable band pass filter; sound-level meter. Technical details in illustrated pamphlet.

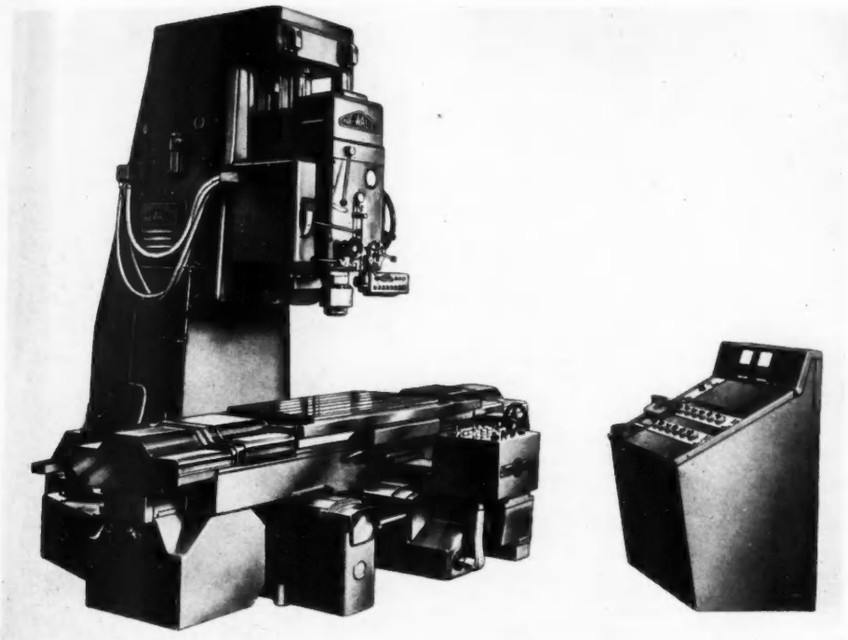


Fig. 7 "Spacematic" precision boring machine with electro-magnetic positioning. (Newall Engineering Co. Ltd.)

The Machine Tool Industry (*continued from page* 572, *vol.* 181)

Our third group of articles on the machine tool industry includes the second and concluding part of an article on drilling, boring and milling, being devoted primarily to the last two operations. In the first section of an article on turning, which follows, we cover centre, capstan, turret and automatic lathes, while copy turning, threading machines and other related equipment will be discussed subsequently. Previous articles in the series have dealt with automatic control systems, machining light alloys, spark erosion, and welding equipment. Many, but not all, of the items have been shown at the International Machine Tool Exhibition, Olympia, which closes to-day.

DRILLING, BORING AND MILLING

(*Concluded from page* 572 *vol.* 181.)

In the conclusion of our article on drilling, boring and milling we shall be concerned primarily with the two latter operations. The first part, published in our issue of last week, dealt with drilling.

BORING

The modern borer is undoubtedly a machine of great accuracy and as such is a natural subject for the more elaborate forms of automatic control which can use the accuracy to advantage. An example is the electro-magnetic co-ordinate setting equipment developed by the British-Thomson Houston Company, Limited, Rugby, in conjunction with H. W. Kearns and Company, Limited, Broadheath, near Manchester, and shown on their stand. This system was described in ENGINEERING, vol. 181, page 477, 1956. Briefly, the co-ordinates of a point are set by dial or punched-card on a control desk and a repeating synchro system moves the worktable to that position, using an electro magnetic sensing head in conjunction with a measuring bar divided into one-inch magnetic units. A positional accuracy of $\pm$ 0·0001 in. can be obtained from a chosen datum. In this way machining time can be considerably reduced.

Other firms exhibiting machines with co-ordinate setting are Newall Engineering Company, Limited, Peterborough, with the AL 2442 which has pre-selected electro-magnetic table positioning; Rockwell Machine Tool Company, Limited, Welsh Harp, London, N.W.2, the KBF2 boring machine with pre-selection of co-ordinate setting and also programme selection; and Charles Churchill and Company, Limited, Coventry-road, Birmingham, 25, who are showing the Scharmann model FB 85 horizontal borer, which has optical measuring and electro-mechanical programming.

The Newall AL 2442 "Spacematic" is the largest of their range of borers with a table capacity of 24 in. by 42 in. and has been introduced to supply a machine with quick and simple setting features. The same B.T.H. electro-magnetic system is used as was described for the Kearns machine. It is fitted with a rapid clamping device for the tools and the three-speed spindle gearbox is controlled by push buttons which operate electro-magnetic clutches. Milling feeds range from ½ in. to 12 in. per minute and the rapid traverse is 60 in. per minute. These are driven from a direct-current motor and a two-speed gearbox, which are also used in connection with the auto-positioning. Machine and control desk are shown in Fig. 7.

Fig. 8 Bemag production borer with pre-selective positioning using length bars. (Rockwell Machine Tool Co. Ltd.)

LENGTH-BAR SETTING

The Bemag K.B.F. 2, exhibited by Rockwell, is illustrated in Fig. 8. It was described in ENGINEERING, vol. 177, page 377, 1954. This is a production boring machine featuring pre-selection of co-ordinate settings (utilising length bars), spindle speeds and feeds. As will be seen from the illustration, the machine has a bridge-type column on which is mounted a longitudinal slide—this longitudinal slide in turn carries the cross slide, each slide being a self-contained unit and incorporating precision end measuring rods held in a magazine. These are electrically selected, the movement of the slides being carried out hydraulically. The machine itself approaches jig-boring accuracy and has been designed in such a way that drilling, boring and milling operations are carried out without the need for marking out, or use of jigs. The longitudinal spindle traverse is 50 in., cross spindle traverse 30 in., working area of table 38 in. by 58 in. and maximum distance between spindle and table 31 in. Vertical adjustment of the table is provided by four ground screws driven by planetary gearing and fitted with backlash eliminators. Table height adjustment is by push button, the table being clamped automatically on releasing the button. Both longitudinal and cross slides are hydraulically clamped when in their working position.

Co-ordinate settings are made by moving two groups of counter wheels fitted to the front of the machine next to the spindle head. Each group of counter wheels contains six figures, the last one reading 0·0001 in. going up in steps of two, all other digits advance in steps of one. Thus the machine can be set, for instance, to 29·4624 or 29·4626. Pre-selection of the co-ordinates for the next hole to be drilled or bored can be made while the machine is still working on the first hole. As soon as the spindle has been retracted from the first hole, it remains for two buttons to be pushed and the machine will automatically re-arrange itself to the previously selected co-ordinates. This machine is provided with 18 spindle speeds from 35 to 1,800 r.p.m. and nine boring feeds, in addition to infinitely variable milling feeds, the spindle being driven by a 5½ h.p. motor.

OPTICAL METHODS

Jig borers all incorporate some accurate means of setting the table position, though the means may be different and are not always automatic. H. W. Kearns, in one series of

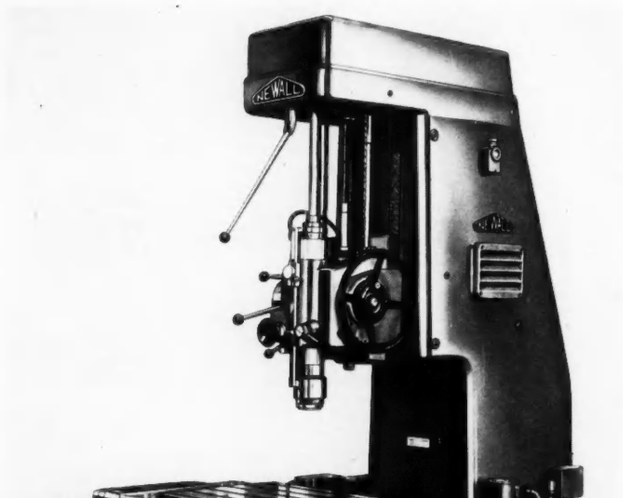


Fig. 9 Jig borer, with optical setting. (Newall Engineering Co. Ltd.)

machines, employ the "Optimetric" system using steel scales and verniers which are projected on to screens measuring 4 in. by 1½ in. This enables setting to be made to 0·001 in. with errors not exceeding 0·00025 in. Steel rules are used on other machines. The Société Genevoise on their "Hydroptic" machines (of which they are showing several models) use built-in alloy rules, divided on the same machines as are used for the national and international standards of length, which are viewed on projection screens and setting is by micrometer heads. Co-ordinate readings can be set to ± 0·0001 in. and the guaranteed accuracy for all displacements of the worktable and spindle saddles is ± 0·0002 in.

The Kearns machine, model OB, which has the Optimetric system, is a new addition to their range. The revolving table is 2 ft. 6 in. square and the spindle diameter is 2¾ in. The optical system was designed in conjunction with Hilger and Watts, Limited.

The main table houses a mechanism which enables the revolving table to be rotated easily on a ball-race, and it can be locked at 90 deg. intervals. At the left-hand end of the main bed are three self-contained units, the nine-speed main gearbox, the feed box and a distribution unit. Mounted at the back of the main bed are two British Standard totally enclosed A.C. motors. Drive from the 5 h.p. main motor is transmitted to the gearbox by a plastic/chrome-leather belt.

A cushioned drive by a similar belt is provided between the main gearbox and the spindle slide. A change-gear arrangement in the spindle slide gives a total of 18 speeds to the spindle. Normally these speeds range from 15 to 750 r.p.m., but higher speeds are available. The spindle slide is balanced, and the spindle sleeve is mounted on special precision ball and roller bearings.

A feature is the provision of a special nitrided cast-iron bush through which the super-finished nitrided steel spindle slides in the spindle sleeve. Spindle and sleeve always rotate together as one unit. A new departure in this machine is the use of a spindle feed mechanism completely enclosed in a light-alloy casting. This arrangement gives full support to the spindle bearing, at the same time reducing the overhung weight to a minimum.

Lubrication to the spindle slide is effected through an automatic plunger pump which draws oil from a fabricated steel sump bolted to the bottom of the spindle slide. This sump is designed in two sections. One carries a suitable lubricant for the spindle bearings and gearing, and from the other a separate hand-operated pump provides the correct type of lubricant for the sliding ways.

The machine is provided with six feeds in two ranges, one in cuts per inch and one in inches per minute. Both ranges apply to all the traverses on the machine.

The optical projection screens are fitted to the vertical adjustments of the spindle slide and boring stay, and the transverse movement of the table. The graduations on the steel rule are projected on to a large screen on the same side of which the vernier graduations are marked. Thus parallax errors are impossible.

The electrical equipment, which is suitable for A.C. supply, includes control gear housed in a dust-proofed sheet-steel case fixed to the rear of the vertical column. This panel controls both the 5 h.p. main motor and 1 h.p. rapid traverse motor. Both motors are braked by a D.C. injection system. On the bed of the machine is mounted a control unit which is fitted with three push buttons, giving "start forward," "start reverse" and "stop" to the main motor. Also included are a pneumatic switch for operating the optical pilot bulbs and a meter indicating the load on the main drive motor.

AIR COOLING

In order to reduce to a minimum the influence of temperature changes between the foundation and the machine, a special foundation grid is supplied which permits air to circulate freely around and under the bed of the machine. The main bed is held to the grid at one end only and any changes of dimensions which take place due to temperature changes cause the bed to move as a whole, and thus a possible cause of distortion is prevented.

Fig. 10 ABA jig borer, with setting by microscope. (Rockwell Machine Tool Co. Ltd.)

As the machine is supplied with a boring stay equipped with an optical system identical to the spindle slide unit, line boring operations can be easily performed.

An optical projection system is also used in the Newall "Optical" jig borer, OP 2436. This is illustrated in Fig. 9. It has the same capacity as the production model of the same number, that is 24 in. by 36 in., and also has the increased sturdiness of more recent versions. There are four spindle feeds ranging from 0·002 in. to 0·008 in. per rev. in both directions. There is differential clamping of the feed box interlocked with the elevating motor control, and the main control lever gives fine and coarse hand feed and also up and down power feed. Table location is by an optical projection system, designed and manufactured by Optical Measuring Tools Limited, one of the Newall group of companies. This system incorporates accurately engraved scales calibrated at intervals of 0·05 in.; images

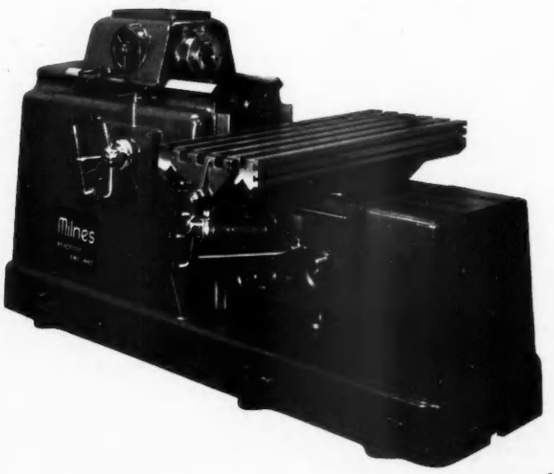


Fig. 11 Sliding head horizontal borer. (Henry Milnes Ltd.)

of both scales are projected on to easily readable screens in a fixed console on the bed of the machine and give readings direct to 0·0001 in., or finer by interpolation. In machines designated for countries employing the metric system, scales are calibrated in 1 mm. divisions and direct readings to 0·001 mm. are obtainable.

Provision is made in the optical system for pre-setting the coincidence graticule in readiness for a succeeding bore, while the machine is in operation. The unique feature of the optical system is that it is possible, having set to the workpiece datum, to set the system so that a complete zero reading of both inches and decimals appears on the screen, thereby making it unnecessary for the operator to add certain fixed measurements to each reading, as usually applies. The setting of the scale line in relationship to the screen is such that a repetitive accuracy of 0·000025 in. is attainable.

A precision jig-boring machine of medium capacity is the Matrix 59 exhibited by the Coventry Gauge and Tool Company, Limited Fletchamstead, Coventry. It has a work table measuring 18 in. by 12 in. All movements are power operated by separate electric motors, and both rapid and fine hand feeds are also incorporated. Spindle speeds from 100 to 3,000 r.p.m. can be obtained from the variable-speed motor. Power is used to set the table approximately and the final adjustments are made by hand using direct reading verniers protected by armour-plate glass. The dials read to 0·001 in. and the verniers to 0·0001 in., which is the guaranteed accuracy of table setting. A depth control indicator for use with slip-gauges is also included. All working parts are totally enclosed, giving a very smooth clean finish, and the movement control buttons are mounted on the front panel below the work table.

GLASS SCALES

Also in the same range is the Matrix 50, which incorporates an optical setting system designed by Hilger and Watts, Limited, and using high-expansion glass scales. The setting accuracy is ±0·0001 in. Considerable precautions have been taken to remove the risk of distortion of the workpiece during machining; there are no motors or mechanisms below the work table, and the main drive unit stands apart from the main casting. Anti-vibration couplings are included in the drive. In addition, the table has been designed so that a coolant can be used during machining by the inclusion of a deep channel round the table which connects with the coolant tank and provides an efficient means of chip disposal.

A jig borer for small and medium work being shown by Wickman Limited, Banner-lane, Coventry (who are displaying over 100 machines on six stands) is the Hauser type OP 3. This has a working capacity of 16 in. by 10 in. and spindle speeds from 80 to 3,000 r.p.m. An optical setting system is employed giving a direct reading to 0·001 mm. on illuminated screens. Built-in high-precision standard scales of special glass ensure positioning of the co-ordinate slides to 0·002 mm.

For boring deep holes, Wickman are showing the Carlstedt type HCI. 25-100, a machine suitable for solid boring $\frac{3}{8}$ in. to 1 in., and for trepanning and counter-boring up to $2\frac{3}{8}$ in. diameter holes. The machine is designed for semi-automatic operation. The construction is extremely rigid to reduce vibration and the hydraulic feed arrangement to the boring tool includes an automatic retraction device which operates in the event of overloading. All controls are available to the operator at a centrally positioned control desk.

MICROSCOPE READINGS

Also fitted with an optical setting system is the ABA model VL 600 shown on the Rockwell stand and illustrated in Fig. 10. In this case hairline microscopes with precision lenses are mounted on the two table slides and the scales on which they focus are protected by sheet-metal guards and sealed against the penetration of dust. The microscopes have a built-in light source supplied from a transformer. Both directions of movement also have a steel scale with a moveable index for rough setting. With the optical device, the table can be set to within 0·0002 in.; the microscopes can be read to 0·00005 in.

The machine itself has a useful table area of 16 in. by 26 in. The longitudinal travel is 26 in. and the cross travel 17 in. The maximum distance from spindle to table is 21 in. and the spindle has a travel of $8\frac{1}{8}$ in. There are twelve spindle speeds from 31 to 1,400 r.p.m. and eight power feeds. There are also fast and slow hand feeds.

A new horizontal boring machine, made and shown by Henry Milnes, Limited, Bradford, 8, embodies a principle which hitherto has been little used, but which is now becoming recognised as being of importance and merit. This is the fixed-spindle sliding head where the head slides on horizontal guides. The inherent advantage of this is extreme spindle rigidity with the boring tool having a fixed and constant overhang. By means of guides the head can be given straight line motion and on this machine inverted double-V's are used which have the additional advantage of being self-aligning and self-compensating for wear. The use of modern slideway grinding machines make the hitherto expensive double-V's a commercial proposition.

Tests for roundness and parallelism show the advantages of this system of boring, and it has been found that tool trail on the return stroke is either eliminated altogether or reduced to a minimum. The machine is illustrated in Fig. 11.

The spindle runs in two precision Timken bearings and has a No. 50 International quick taper bore which is $5\frac{7}{16}$ in. outside diameter and is suitable for holding and driving large diameter boring bars such as are used for snout boring.

A facing and recessing head is available for this machine for work up to approximately 15 in. diameter. It is an independent unit bolting direct on the spindle nose with automatic forward and reverse feeds.

The machine has a long table at right angles to the head guides, supported by a box knee which has four vertical V-guides, one at each corner, with a worm and wheel operated elevating screw in the middle. Power feeds and traverses are provided to both the knee and the table by independent electric motors, the table feeds being suitable for milling.

As the boring head incorporates a standard milling-machine spindle, it follows that in addition to boring, any type of milling cutters can be used, a suitable range of spindle speeds being provided.

It is proposed to market a range of these

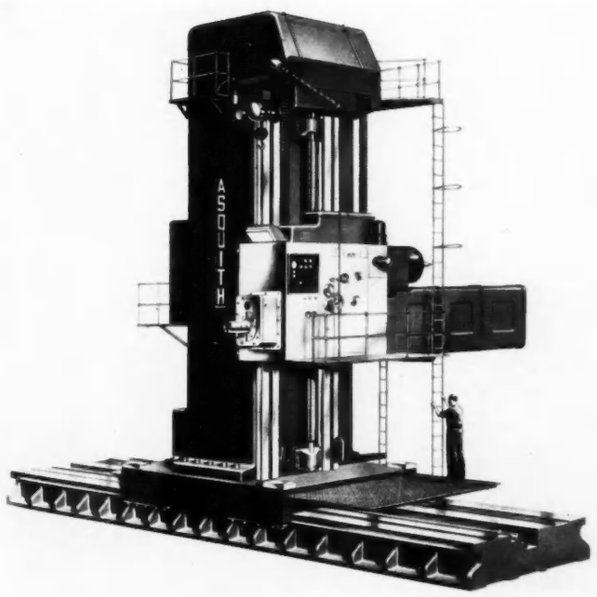


Fig. 12 Ram-type horizontal dual-purpose machine for milling and boring. (Drummond-Asquith (Sales) Ltd.)

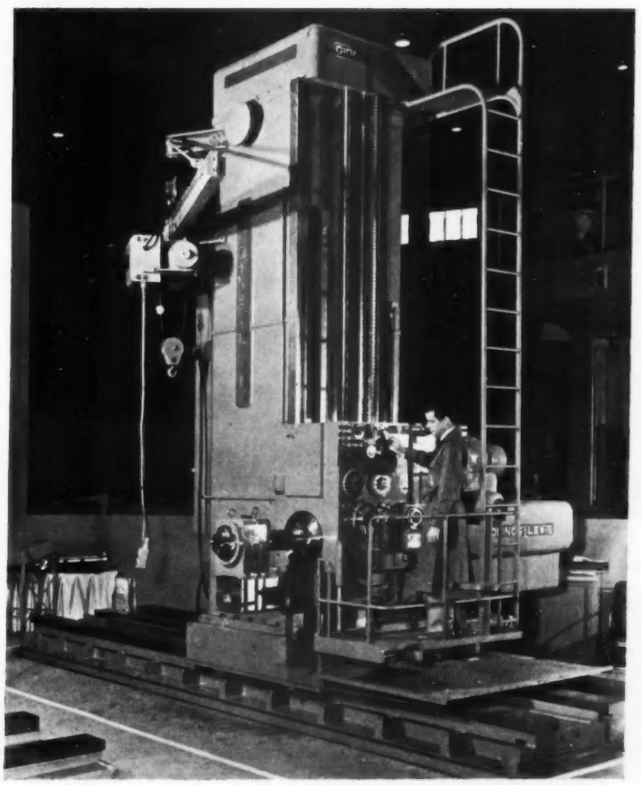


Fig. 13 Giddings and Lewis 6 in. spindle horizontal milling, drilling and boring machine. (Rockwell Machine Tool Co. Ltd.)

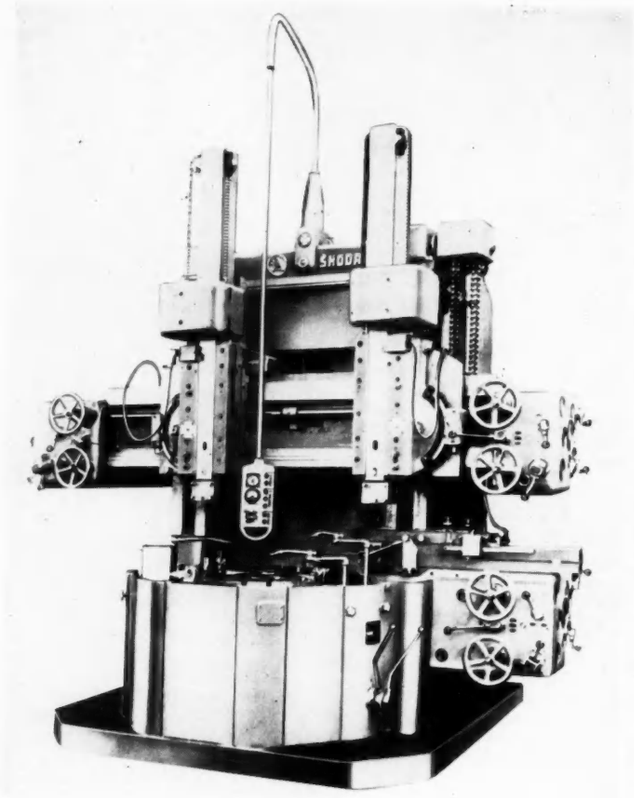


Fig. 14 Skoda vertical boring and turning mill. (Selson Machine Tool Co. Ltd.)

machines in various sizes and types, as single purpose boring machines or universal machines combining boring, milling and facing.

The size of one model of the machine is: head traverse 20 in., spindle speeds 12, 40 to 750 r.p.m.; number of feeds 4, from 0·0025 in. to 0·020 in., per revolution of the spindle; table size 48 in. by 20 in.; centre of spindle to table top maximum 15 in.; working length of table traverses 30 in.; main drive motor 7½ h.p. weight 3½ tons.

A vertical fine boring machine, made by Kellenberger is being shown by Dowding and Doll, Limited, 346 Kensington High-street, London, W.14. It is one of a range, and has a boring depth of 39⅜ in. and diameters from ⅞ in. to 20⅞ in. One special feature is that the boring tool can be set for diameter while the spindle is still rotating. This enables undercut diameters to be readily set. The machine is fitted with a jig table and co-ordinate positioning may be attained with optical microscopes and measuring blocks or cylindrical rods and dial indicators.

Also shown by Dowding and Doll is the Swiss DIXI 60 horizontal optical precision jig-boring machine. With the provision of optical microscopes, settings within an accuracy of 0·0002 in. may be obtained. The design of the machine, incorporating two substantial vertical columns bridged for full support, provides maximum rigidity for the spindle carriage. The machine incorporates both axial feed to the spindle and longitudinal table traverse, facilitating boring operations of both light and heavy duty.

HEAVY-DUTY MACHINES

Giants among the boring machines are the 120 ton Graffenstaden (of which a model is being shown on the stand of Acbars Limited, 57A Holborn-viaduct, London, E.C.1) and the 10 in. spindle Asquith machine, on the stand of Drummond-Asquith (Sales) Limited, New-street, Birmingham, 2. It has a 100 h.p. spindle drive motor with Ward Leonard control. There are three spindles, 13½ in., 8 in. and 2¾ in. diameter for milling, boring and special high speeds. One man can operate this machine from the platform using the special alignment telescopes, optics and cranes.

The Asquith machine, illustrated in Fig. 12, is fitted with a ram and spindle for heavy boring and milling. It was introduced primarily as a dual-purpose tool, following the tendency to replace planing by milling.

The slide is of heavy proportions and carries a ram of rectangular section which is arranged to house the milling sleeve and spindle. The front of the ram is provided with a facing, to which can be bolted various types of milling attachments and when fitted would be driven by the milling sleeve or the spindle. The flange at the front end of the milling sleeve is arranged to carry milling cutters if so desired, and a surfacing slide attachment can also be fitted to the flange. When this is applied, provision is made to obtain feed changes and full control of the slide, giving the facilities of a built-in facing slide.

The spindle is driven from the milling sleeve and both the spindle and ram have feed and quick power-traverse motions, the latter by one common motor, while the feed motion is obtained by gearing in the slide. Micro-setting is applied to the spindle and ram movements and operated by one common motor. When required for the spindle or the ram, definite leads can be obtained by the use of pick-off gears for screwcutting.

The main slide is fitted to the column slideways and provided with keep and adjusting strips and also with power-operated locks. Milling feeds and quick power-traverse vertically is supplied to the slide and operated by separate motors. In addition, micro-setting is possible, again by a separate motor.

The main driving motor is mounted upon the slide and this in conjunction with speed changes in the slide gives an infinitely variable range. The milling feed range is also infinitely variable and the motors are controlled by Ward Leonard equipment. The slide is balanced by a weight suspended in the column. Automatic lubrication is provided to the slideways on the column.

The column is of wide section, to carry the slide, and of proportions to meet the heavy milling operations. The column is bolted to a base which has feed and quick power-traverse along the bed, also micro-setting, each being operated by a separate motor in a similar manner to the slide. Power-operated locks are used. The bed is of very wide section, again designed with the object of obtaining a very rigid condition for the heavy milling operations.

The Ward Leonard set will be mounted on the floor and the cabinets which house the control gear mounted upon a platform built upon the column. Busbars will be arranged at the back of the bed for the supply to the motors.

An operator's platform is arranged on the slide of the machine so that control can be obtained for all motions. A ladder is also provided down the length of the column.

A push-button panel is built into the slide providing the electrical controls to all motions, and a pendant is provided to control the movements of the ram and spindle traverses and the main driving motor.

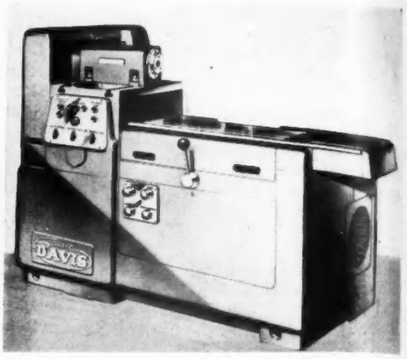


Fig. 15 Horizontal fine borer. (Stuart Davis Ltd.)

Rules and verniers are fitted to all traverses with optical readings. The gear comprises telescopes, prisms and mirrors, where necessary, and the readings are all made from a forward position on the slide.

The ram has a travel of 5 ft. and the spindle travels 6 ft. 6 in. in the ram. The vertical travel of the slide is 15 ft. and the horizontal travel of the column on the bed 33 ft. There are 14 driving motors, that for the spindle being rated at 100 h.p., and the approximate weight is 188 tons. Three smaller sizes are made, with 8 in., 7 in. and 6 in. spindles.

UNDER-ARM SUPPORT

Another machine with a 6 in. spindle is the Giddings and Lewis 460-FUAR shown on the Rockwell stand and illustrated in Fig. 13. Milling, drilling and boring operations can all be carried out on it. The hoist shown is power driven and has a capacity of 2 tons. Its primary purpose is for handling tools and attachments. All machine functions—including inching—are controlled under power, and rapid traverse can be engaged even when the spindle is in motion. Spindle controls are duplicated at the rear of the column. There are 32 speeds, grouped in 4 ranges and 18 feeds in 2 ranges, the highest being 120 in. per minute (rapid traverse). The extension of the spindle is recorded on a counter connected with a slow-feed hand wheel, and an automatic depth stop and trip is incorporated.

The under-arm support carries the tool horizontally for a distance of 48 in. with the same power feeds as the spindle. It can be declutched if desired and the spindle moved alone. The maximum spindle travel is 48 in. The column has a horizontal travel of 72 in. and the headstock a vertical movement of the same amount. The minimum distance from the top of the runway to the spindle centre is 23⅝ in.

A smaller heavy-duty machine is the Skoda SK12 vertical boring and turning mill shown by

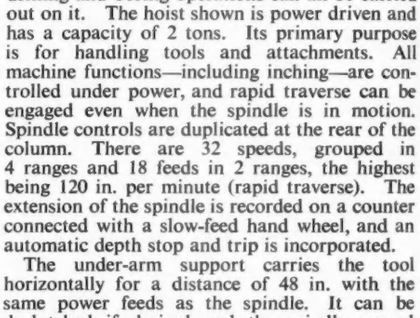


Fig. 16 Deckel universal milling and boring machine. (Burton, Griffiths and Co. Ltd.)

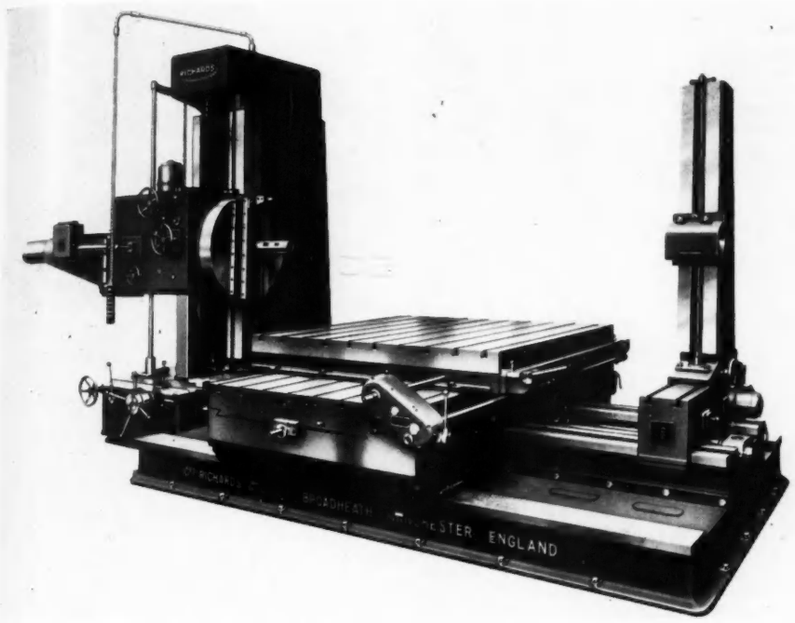


Fig. 17 Electrabore wide-bed milling, drilling and boring machine. (George Richards and Co. Ltd.)

the Selson Machine Tool Company, Limited, Chase-road, London, N.W.10 (one of the 600 Group). This machine has a maximum turning diameter of 49 in. and is built for workpieces up to 4 tons in weight. It is illustrated in Fig. 14.

The high cutting speed—up to 2,000 ft. per minute—allows full utilisation of the hardest cutting tools and is infinitely variable, being adjustable without interruption of working. Controls have been reduced in number to the essential minimum, and are conveniently laid out so as to reduce idle time. The clamping and unlocking of the heavily reinforced cross rail is entirely automatic, thereby greatly simplifying its raising and lowering. Lubrication has been specially studied and all important assemblies are automatically lubricated by independent pumps and baths.

Another machine on the Selson Company's stand is the Skoda HVF160D. It is a heavy-duty boring, drilling and milling machine with a boring capacity of 3 ft. 3 in. It is capable of dealing with drilling, boring, reaming, milling and screw-cutting operations on large and heavy workpieces, these being clamped to a plate that is separate from the machine proper.

A high-power main motor gives a wide range of spindle speeds, permitting cemented carbide tools to be used for boring as well as milling. Spindle and faceplate drives are independent, an arrangement which affords the most varied combination of operations, and all drive and feed shafts are carried in special anti-friction bearings. A typical refinement is the inclusion of a speed indicator for both spindle and faceplate.

Other features include the provision of a small axial movement in the faceplate slide to allow adjustment of the tool in the cut when a milling cutter is fitted to the faceplate.

INVERTED-SPINDLE BORER

An unusual machine among the borers is the Krause inverted-spindle fine boring machine being shown by Drummond-Asquith. This has a flat topped table and no column, the spindles being fed up from below. A two-spindle model is being shown, but others are made with as many as eight spindles. The design is not new but the machine lends itself to production work of such items as cylinder blocks by its ease of loading. There are a wide range of spindle speeds and feeds and the bores produced are round and parallel to within 0·005 mm. The worktable can be located to within 0·002 mm. by a system of ratchets and stops. The machine is capable of boring holes 13 in. deep by $5\frac{7}{8}$ in. in diameter.

The horizontal fine boring machine exhibited by Stuart Davis, which is illustrated in Fig. 15, is operated by a combination of electrical and hydraulic elements which suggests that it could easily be adapted for computer control. The various cycles are governed by adjustable cams and plungers and include fast approach, feed, dwell, stop and return. A master throttle lever can be used to control table movement. The table travel is 15 in. and the working surface 28 in. by $6\frac{1}{2}$ in.

There are several machines on exhibition which fall into the "general purpose" type, as they are suitable for drilling, boring, tapping and milling. Some have already been mentioned. One, shown by Kitchen and Wade, is a horizontal machine, the spindle slide of which has horizontal and vertical traverses that can be either power or hand operated. There are 36 spindle speeds and nine rates of feed, which cover machining requirements for most materials. The spindle is 3 in. in diameter and the capacity is $3\frac{1}{2}$ in. in solid mild steel. The reverse motion fitted for tapping operations speeds up the spindle two and a half times, cutting down tapping time considerably. All slides are fitted with built-in verniers to allow accurate setting. A special support is available for use in milling operations.

Another machine of similar type is that shown by George Richards and Company, Limited, Altrincham, which is illustrated in Fig. 17. This is the No. 5 "Electrabore" wide-bed model and has a traversing spindle 5 in. in diameter. The facing head will take work up to 54 in. in diameter and the main table is 11 ft. by 6 ft. It is one of a series with varying capacities and is intended for heavy-duty work on large workpieces. The ranges are somewhat similar to the earlier "Hydrabore" machines of the same firm, but the hydraulic operation has been replaced by electronic. The firm's Prismatic slides have been incorporated, which spread the cutting forces over a large area. Several improvements have been embodied in the machine, including a sturdier main upright which encloses the balance weight, and the use of taper roller bearings on the main spindle. The spindle frame has also been redesigned.

The drive to the main spindle is by an endless roller chain, the sprocket being mounted on an independent sleeve to relieve the main spindle of any chain load. This drive is another patent of the firm. The facing head has 24 speeds, ranging from 1·66 to 130 r.p.m. and there are eight reversible feeds to the tool slide, ranging from 0·01 in. to 0·125 in. per revolution. These are controlled by a single lever. The facing slide is also fitted with a rapid power-traverse. The traversing spindle has 36 speeds, from 1·66 r.p.m. to 300 r.p.m. To facilitate the accurate setting of the upright and boring stay, and the cross and longitudinal traverses of the table, illuminated optical projectors are fitted for reading the verniers.

A universal milling, drilling and boring machine is the Deckel F.P.2 shown on the stand of Burton, Griffiths and Company, Limited. It is illustrated in Fig. 16. One particular advantage of this type of machine is that clamping time is reduced as the head can be inclined at any angle between vertical and horizontal, so that a great number of operations can be carried out on a work-piece without having to re-position it. In this machine the work clamping area is $27\frac{1}{2}$ in. by $9\frac{1}{2}$ in. and the table has longitudinal and vertical movements of 15·8 in. There are both 18 feed and spindle speeds, the latter ranging from 40 to 2,000 r.p.m.

MILLING

Milling is one of the more popular methods of machining, as it offers great facilities for the removal of comparatively large quantities of metal

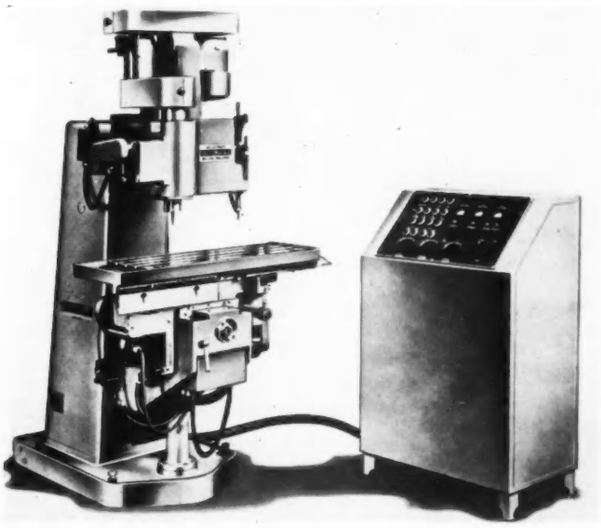


Fig. 18 Velvetrace copy milling machine using spark control. (Buck and Hickman, Ltd.)

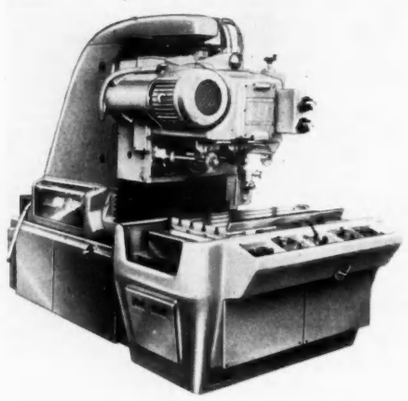


Fig. 19 Hydro-copying machine for turbine blades. (Dowding and Doll, Ltd.)

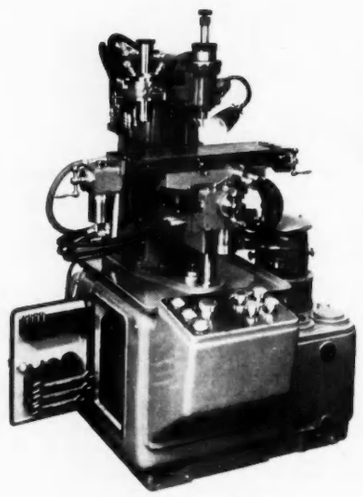


Fig. 20 Tracemaster hydraulic copy miller. (Hayes Engineers (Leeds) Ltd.)

at a reasonable cost and with considerable accuracy. Various shapes can be machined directly and both profiles and contours are comparatively easily obtained. The method lends itself to use in flow lines and to automatic control, both for a programme cycle or for individual items. An enormous number of milling machines were exhibited and it is only possible to describe a very few.

Copy milling is greatly employed in the production of dies from very small components up to the largest mouldings; various methods are employed in copying in controlling the milling spindle from the follower stylus; alternatively the spindle may be directly controlled from some electronic or computer system as, for example, in the Ferranti machine and the E.M.I. device.

SPARK FOLLOWER

Buck and Hickman, Limited, Whitechapel-road, London, E.1, were showing the Pratt and Whitney Velvetrace milling and die sinking machine illustrated in Fig. 18, which employs an unusual device in the follower control.

As the stylus passes over the master die, it does not touch it but a spark passes continuously from the stylus to the die and the slightest variation in spark gap produces a proportional change in voltage across the gap, which is, in turn, amplified and the resultant signal used to control the drives to the spindle quill. The stylus passes over the master in a series of strokes and is fed across until the complete surface has been covered. There being no mechanical motion in the stylus, the signal has no time delay and the master is not damaged by rubbing contact. The machine has a table with a working surface 12 in. by 34 in.; speeds and feeds are both infinitely variable and the step feeds can be chosen between 0·002 in. and 0·020 in. per stroke. The hydro-copying machine shown by Dowding and Doll, Limited, Greycoat-street, Westminster, London, S.W.1, is illustrated in Fig. 19. It is known as the Rigid Model ST.100/2 and has been specially designed to produce the larger type of steam-turbine blade up to 16 in. long. Having twin horizontal spindles it can handle two blades at a time and is fitted with longitudinal and traverse pick-feeds, hydraulic longitudinal traverse and a stroke limiting device for copy milling. The machine is capable of sweep milling along the axis of the work table; the hydro cutting motion operates in both vertical and transverse directions. The table size is 35½ in. by 17¾ in.

Pantograph copying is used in the machine shown by Taylor, Taylor and Hobson Limited,

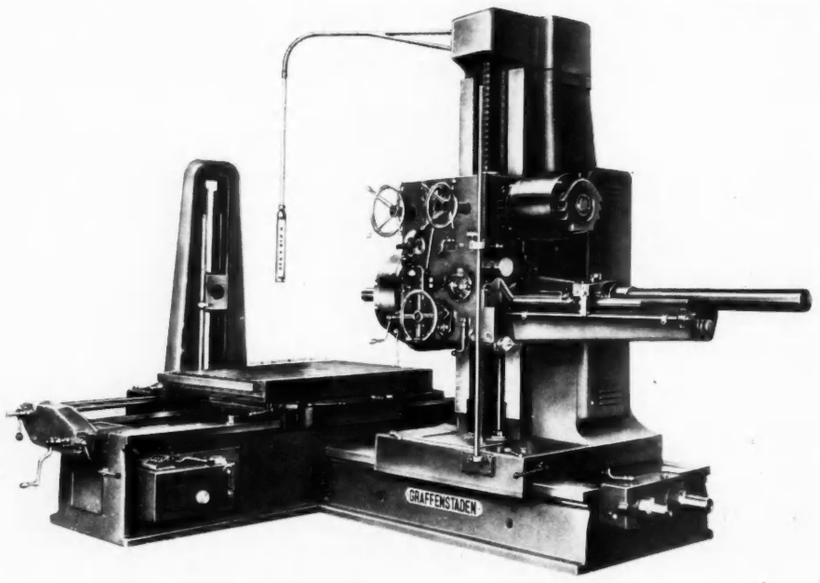


Fig. 22 Graffenstaden plano-miller. (Acbars Ltd.)

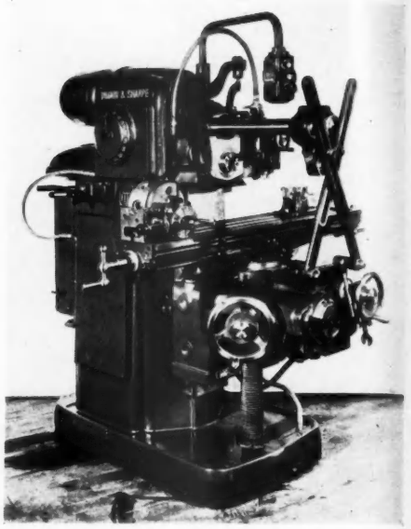


Fig. 21 Rangemaster universal miller. (Buck and Hickman Ltd.)

Leicester. It is a high-speed vertical milling machine also capable of die sinking. The spindle is coupled to a tracer by a pantograph arrangement so that the cutter follows truly in both horizontal and vertical directions. Reduction by the pantograph is variable from a ratio of 1½ to 1 down to 7 to 1.

CONSTANT FEEDS

Particularly designed for the automatic milling of cylindrical cams, worms and trapezoidal threads is the Kopp E.S.F.1 single-spindle hydraulic automatic tracer control machine shown by Wickman, Limited, Tile Hill, Coventry. Three sizes are available with single or double opposed spindles and they are capable of cutting cams up to 8 in. diameter. For the same purpose is the Kopp U.K.F.2 machine, which can also use end-milling cutters. Control for the various table movements is obtained from hydraulically operated tracer valves and plate cams. Provision is also made for maintaining constant feeds irrespective of the shape of the work. Cutter speeds can be chosen from 63 to 2,000 r.p.m.

Hayes Engineers (Leeds), Limited, Gelderd-road, Leeds, 12, were showing their Tracemaster, which is illustrated in Fig. 20. This is a fully automatic copy-milling machine using hydraulic control from the stylus; the table reverses automatically at the end of each stroke by means of adjustable stops attached to it. The speed of rise and fall of the knee and the speed of table traverse are pre-set by hand, after which movement is controlled by the copying valve. The table is traversed at a constant rate of feed relative to the form being copied and the machine is capable of working on vertical faces. The table has a traverse of 16 in. by 8 in. and the knee a vertical movement of 8 in. under hand control, and 3½ in. under hydraulic control. Cross-slide feeds are infinitely variable from 0·005 in. to 0·250 in. per minute and table traverse from ¼ in. to 6 in. per minute. The firm are also showing the Diemaster mould milling machine and the Cam-Master, a self-contained fixture for copy-milling cams which can be used with any vertical miller of suitable capacity.

GENERAL PURPOSE MACHINES

Many of the machines on show were classed as universal, in that they were suitable for all general types of milling; a typical one is the Rangemaster, made by Brown and Sharpe Manufacturing Company, and exhibited by Buck and Hickman, Limited; it is illustrated in Fig. 21. The machine has a longitudinal feed of 28 in., a transverse feed of 12 in. and a vertical feed of

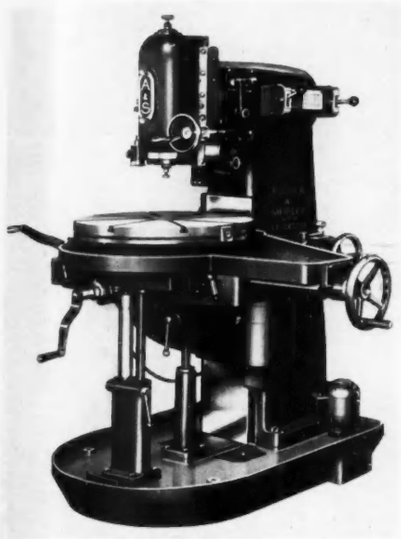


Fig. 23 Continuous milling machine. (Adcock and Shipley, Ltd.)

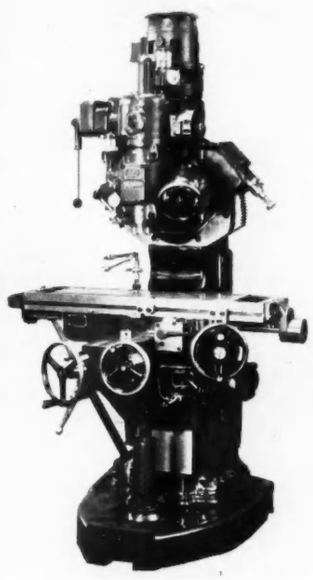


Fig. 25 Swivel-head milling machine. (James Archdale and Co. Ltd.)

20½ in., all of which are automatic. The distance from the centre line of the head spindle to the column face can be varied from 2 1/16 in. to 24 1/16 in. and the height from the main spindle to the top of the table from 4 1/2 in. to 21 7/8 in. A very large number of accessories are available with this machine to handle the different types of work. Eighteen spindle speeds are provided ranging from 40 to 1,530 r.p.m.; they are selected by rotating a single lever. The feeds are selected in a similar way.

Several general purpose machines are being shown by Adcock and Shipley, Limited, Ash-street, Leicester, some of which have not been previously exhibited. They are mostly of a conventional form. The smallest one having rapid traverse in all directions is the No. 2 JUR universal milling machine, which has a table size 50 in. by 10 in., and incorporates a positive backlash eliminator. The 2VR is a continuous milling machine, which is also on show for the first time. It is driven by a 3 h.p. four-speed motor which is used in conjunction with a back gear to give eight spindle speeds. It is particularly suitable for the mass production of components which can be face-milled or straddle-milled, and can also be used for continuous production of components which have to be slotted, in those cases where a slightly convex or concave surface at the bottom of the slot is not detrimental. Loading and unloading can be carried out on the table while machining is taking place on another part. The machine is shown in Fig. 23.

A production milling machine of a heavy-duty type is the HyPowermatic, made by Cincinnati Milling Machines, Limited, Woodlands Farm-road, Tyburn, Birmingham, 24. There are two models, plain and duplex, and the range comprises 42 sizes in both styles, all being available with or without tracer control.

Heavy-duty machines allowing full use to be made of tungsten-carbide cutters are the Heller milling machines shown by Wickman, Limited. Double movements are effected by electro-hydro-mechanical means, electrically controlled, and a backlash eliminator is fitted to allow climb milling. Automatic work cycles can be provided when the machine is equipped with programme control; it can also be fitted for tracer control and with copy-milling devices. Air cooling is provided by a fan. The horizontal model has a working-table surface of 63 in. by 14 in., and 16 spindle speeds. The vertical version has a working area 78 in. by 18 in. and also 16 spindle speeds.

PLANER-MILLERS

The planer type of boring and milling machine is represented by the Graffenstaden model AP.101, illustrated in Fig. 22. This is shown by Acbars Limited, 57a Holborn-viaduct, London, E.C.1. In this machine the table moves at right angles to the main bed and has a traverse of 78 in., there being nine feeds. The column moves along the bed parallel to the spindle over a distance of 31 in., and the work-table has a surface of 53 in. by 43 1/8 in. It can be rotated through a complete circle. The 4 in. spindle has 18 speeds ranging from 8 to 1,000 r.p.m.

Another planer miller is the Morey machine shown by the Selson Machine Tool Company, Limited, Cunard Works, Chase-road, North Acton, London, N.W.10; this is shown in Fig. 24. The working surface of the table is 48 in. by 120 in. and the distance between the columns 60 in. The machine has been developed for the purpose of machining plates and forgings from which aircraft skins are built up, and which must be milled to fit the airframe spars. It has a wide range of spindle speeds, enabling it to be used on ferrous or nonferrous materials as well as plastics, and both carbide and high-speed steel tools can be used. All operations are controlled from three hand wheels; dials, buttons and gauges having been dispensed with. Although it can work at a fairly high speed, tolerances as close as 0·002 in. can be maintained.

James Archdale and Company, Limited, Ledsam-street, Birmingham, 16, are showing several milling machines, among them being the 18 in. swivel-head version shown in Fig. 25, which is designed for work on light metals and for light duty on cast iron. Automatic reversible feeds and quick power-traverses are incorporated in all three table movements.

Also shown by Archdales is the 34 in. vertical milling machine, an improved version having a more robust spindle drive capable of running at high speeds. It is particularly suitable for carbide or high rake milling. Magnetic brake and clutch give gentle starting and a precise control to the spindle; the knee has a hydraulic counter-balance which gives easier hand vertical adjustment and a long elevating-screw life; 24 feeds are available.

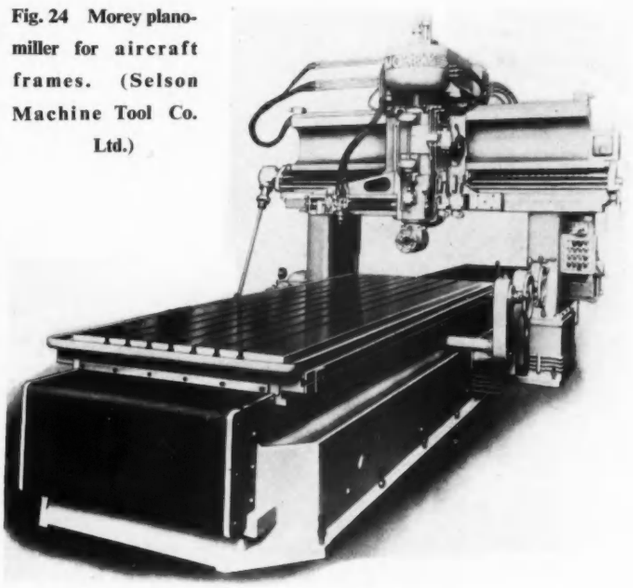


Fig. 24 Morey plano-miller for aircraft frames. (Selson Machine Tool Co. Ltd.)

A planer milling machine with one vertical head on the cross slide and two horizontal heads, one on each upright, is being exhibited by Kendall and Gent, Limited, Hyde-road, Gorton, Manchester. This has a total traverse of 16 ft. and a table working surface of 5 ft. by 14 ft., eight table feeds are available, and eight head feeds. The firm are also showing an open-side milling machine with one vertical milling head on the cross-slide and one horizontal milling head on the upright, each being driven by a 20 h.p. motor; all traverses are infinitely variable, and automatic retraction of the spindles on completion of the cut is included. The useful working surface is 4 ft. by 11 ft.

A vertical reciprocal mill is shown by the Sykes Machine Tool Company, Limited, Hythe Works, The Hythe, Staines, Middlesex. Table movement to left or right of the centre line can be selected at will, with the advantage that one batch of components may be replaced while the other is being machined; a pneumatic clamping arrangement is available. The cutter is 15¾ in. in diameter and runs at 1,300 r.p.m.

SPECIAL MACHINES

Apart from the many general purpose machines on show, there are several examples of special purpose tools. Among these are the automatic transfer machines, of which Drummond-Asquith (Sales), Limited, are showing a rotary example. The Unimatic machine shown by James Archdale has already been mentioned. The Asquith machine has five stations and the worktable revolves twice per cycle. The components are manifolds for motor-car engines, and are turned over in the duplex fittings at the conclusion of each table revolution. Drilling, countersinking, tapping and boring are the operations carried out.

Special purpose machines, also largely used for motor-car engine parts, are the Precimax range shown by John Lund, Limited, Eastburn Works, Cross Hills, near Keighley. These have horizontal spindles and can be either single or double ended. The heads are independent units made in a wide range of sizes and types, and are driven separately by endless belts. Micrometer adjustment is provided for the worktable. Table traverse is by hydraulic power and more than one controlled stop for an operative station can be used.

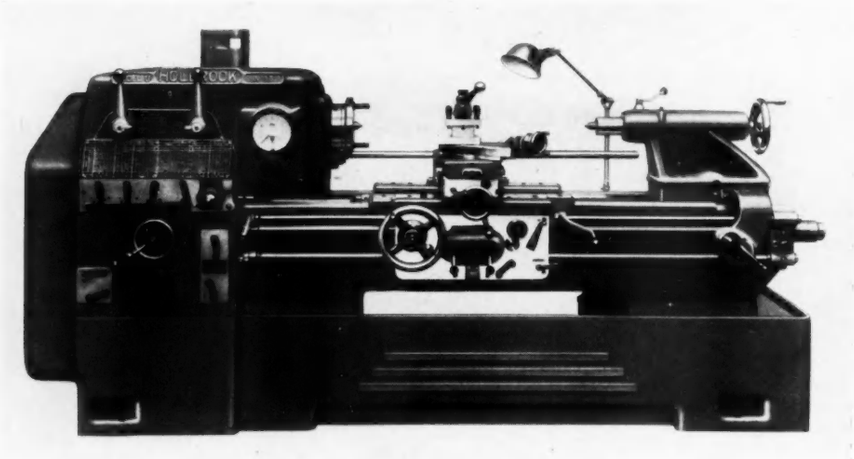


Fig. 1 24 in. swing toolroom lathe, with infinitely variable spindle speeds, ranging from 3 to 725 r.p.m. (Holbrook Machine Tool Co. Ltd.)

The Machine Tool Industry

TURNING, SCREWING AND THREADING

It is convenient to group machines for threading with those for turning, for although special-purpose machines exist and are widely used for these two operations, both can be, and often are, carried out on the oldest of all turning machines —the centre lathe. Several specialised machines have, of course, been developed from the centre lathe, but these will be dealt with later. The first part of the present article will be devoted to centre, capstan, turret and automatic lathes; while a second part will complete the section on automatics and cover, in addition, copy turning, threading and various special items.

CENTRE LATHES

The centre lathe itself exists in several forms, of which perhaps the simplest is the brass-finishers' lathe, and the most complicated the toolroom machine. In between these extremes there are many variations, a common example of which is the surfacing and boring lathe, which has no tailstock and is usually equipped with a hexagon turret on the saddle. In all its variations the centre lathe continues to find a useful place in all engineering shops, indeed it is one machine which is virtually indispensable. No fundamental changes in design were shown at the exhibition, indeed, none could be expected, but the developments which have been proceeding steadily for years, starting with motorisation and leading to all-geared heads with specially rigid construction and high power to suit modern cutting tools, have produced a fine all-round machine of which several examples were shown.

The 24 in. swing toolroom lathe shown in Fig. 1, which is made by the Holbrook Machine Tool Company, Limited, 44/48 Martin-street, Stratford, London E.15, is a typical example of modern design. Powered by a built-in 7½ h.p. motor, the lathe has infinitely-variable spindle speeds in four groups, the actual range being from 3 to 725 r.p.m. Speeds are indicated by a tachometer built into the headstock, with a knurled knob beneath it for speed control. A dial-change gearbox provides 60 direct changes of English pitches, and change gears for Metric, Module and coarse pitches are provided.

One machine of a completely new range introduced by John Lang and Sons, Limited, Johnstone, Renfrewshire, is illustrated in Fig. 2. This is a 20 in. swing centre lathe; two other machines, of 16 in and 24 in. swing, complete the range. The full range of sliding, surfacing and screw cutting operations is carried out by this lathe, which is provided with a machined facing so that a hydraulic copying attachment can be fitted if required. The spindle speed control arrangements are particularly simple and effective, a range of spindle speeds from 10 to 1,470 r.p.m. is provided, with 24 steps, control being through a pre-selector dial which also indicates the cutting speed for any work diameter at the selected spindle speed. Movement of the speed-change lever stops and brakes the gears in the headstock, engages the pre-selected gears and re-starts the spindle. An interlock prevents the gears from sliding until the shafts have been braked, and an idling drive is operated automatically to assist engagement while the gears are sliding.

AUTOMATIC SETTING OF SPINDLE SPEED

From America comes the Monarch " Dyna-shift " lathe shown in Fig. 3. It is made by the Monarch Machine Tool Company, Sidney, Ohio, and was exhibited by their agents in this country, the Rockwell Machine Tool Company, Limited, Welsh Harp, Edgware-road, London, N.W.26. The machine is available in two spindle heights, giving 10 in. or 13 in. swing over the cross-slide and is driven by a 10 h.p. motor. There are 36 spindle speeds, from 14 to 1,750 r.p.m. the gear changing being by means of hydraulic clutches, controlled by hand levers on the apron and at the headstock. Two dials are mounted at the front of the headstock, one being graduated in spindle speeds in r.p.m., while the other is a compound dial marked in surface speeds and work diameters. Setting of the appropriate dial to the work diameter and recommended surface speed by the operator sets the correct spindle speed automatically; all the operator needs to do then is to engage the spindle drive by means of the hand lever. Speeds can be pre-selected while the machine is in operation, and in any order required, and once the pre-selectors have been set for a work-piece, any number of similar pieces can be turned without the operator giving any attention to the speed he is using.

The machine has all the normal features associated with a toolroom lathe, and has, in addition, a small but useful novelty in the tailstock. This is provided, with a two-speed spindle drive from the normal handwheel. It is thus possible to move the spindle rapidly for ordinary positioning, and to move it slowly for sensitive drilling.

SMALL MACHINES

Typical among the smaller lathes was the 5 in. " Chipmaster " sliding, surfacing and screw-cutting lathe shown by the Colchester Lathe Company, Limited. This machine, a new model, has an infinitely variable speed range, from 30 to 2,000, or from 45 to 3,000 r.p.m., the gears in the headstock being disengaged when the spindle is running at high speeds; the drive is then direct by rubber and nylon belt to ensure freedom from vibration.

Representative of the smaller products of the Swiss machine tool industry is the 4 in. Simonet bench-type tool-makers' lathe shown by Acbars, Limited, 57a, Holborn Viaduct, London, E.C.1, and illustrated in Fig. 4. This machine is available with a very large range of accessories and special equipment. Basically, it has a three-step cone-pulley drive, and can be driven from any convenient source of power, but there is available an individual electric drive, as shown in the illustration. This drive can also be used with a grinding attachment. Spindle speeds vary, according to the drive, from 14 to 2,750 r.p.m. For screw cutting the lathe has a range of 29 British or 24 Metric threads. Numerous special attachments such as collets, faceplates and chucks, milling and dividing heads, lever-operated tailstock and inclined tailstock turret head are available; in fact, this machine, if fitted with all the available extra attachments, demonstrates admirably the versatility of the centre lathe.

MODIFIED CENTRE LATHES

The number of modifications possible on a centre lathe is legion. The only difficulty which arises as a result of modification is to know when a machine ceases to be a centre lathe and passes into another group. There are modifications

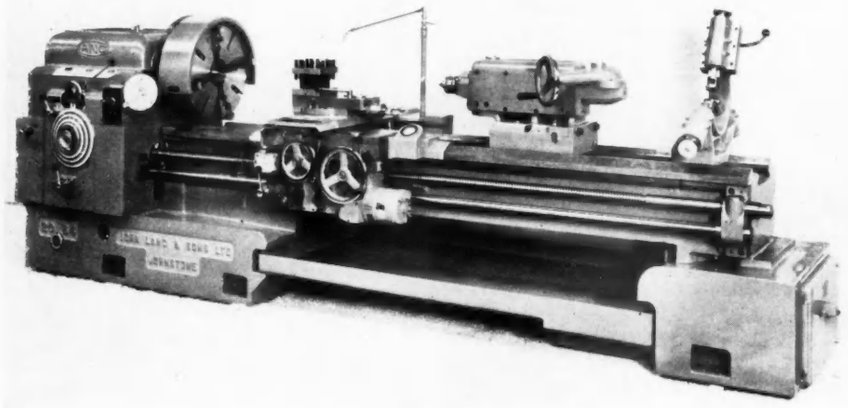


Fig. 2 Sliding, surfacing and screw-cutting lathe, 20 in. swing, with pre-selector for spindle speeds. (John Lang and Sons Ltd.)

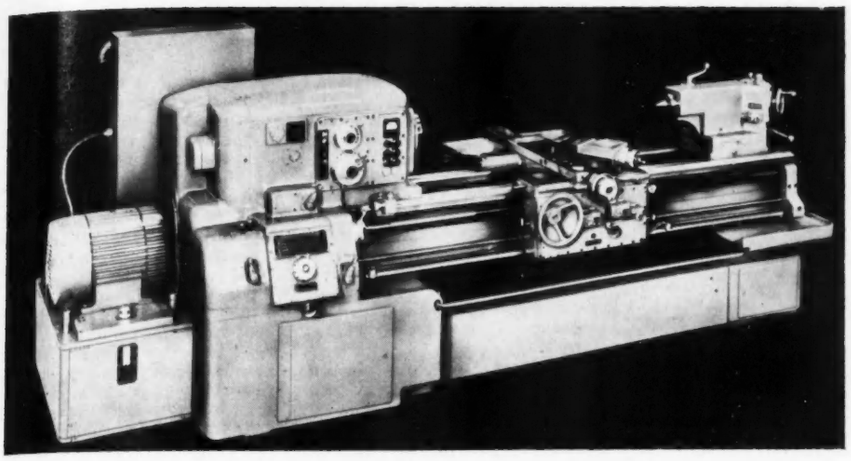


Fig. 3 Monarch " Dyna-shift " lathe, with automatic setting of spindle speeds from dials indicating work diameters and surface speeds. The tailstock is provided with a two-speed spindle drive from the normal handwheel. (Rockwell Machine Tool Co. Ltd.)

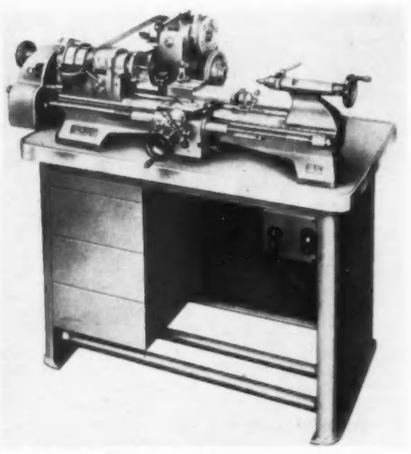


Fig. 4 Bench-type tool-makers' lathe, by Simonet, Switzerland. Available with a large range of special equipment and accessories. (Acbars Ltd.)

like the tandem system of two driving motors employed in the Czech Skoda lathe shown by the Selson Machine Tool Company, Limited, Cunard Works, Chase-road, London, N.W.10, which do not alter the basic design or use of the machine. This arrangement of motors facilitates frequent stopping, starting and reversing, and provides a starting torque equal to the nominal torque.

Another modification in the same class is the sliding bed and back-bed provided on the Stanley 10½ in. centre lathe shown by M. C. Layton, Limited, 96–98 Victoria-street, London, S.W.1. The sliding bed gives a gap, adjustable for width at will, in which large diameter components can be faced and bored, and is a feature which is quite well known, making the lathe, in effect, both a gap-bed and a straight-bed machine, the other features remaining unaltered. The addition of a back-bed, with a compound saddle, enables work of much larger diameter to be machined on its outside diameter than would normally be the case.

An addition of a different type is the hydraulic attachment for screw cutting which can be supplied with the Demoor centre lathe, exhibited by George Cohen, Sons and Company, Limited, Sunbeam-road, London, N.W.10. Internal or external, parallel or taper screw cutting can be carried out with this attachment, the work being held in the normal way between centres, in a chuck, or through the spindle. With the attachment in position the lathe becomes, in effect, a special-purpose screwing machine, but it loses nothing of its normal machining capacity, and can, in fact, be used for boring or turning a component prior to screw cutting, thereby eliminating loss of time incurred in transferring the component from one machine to another. The screwing attachment can be removed, leaving the machine as a normal lathe.

Another type of modification of a centre lathe is typified by a new model exhibited by Wyvern Machines, Limited, Percy-road, Leicester. This is basically a sliding, surfacing and screw cutting lathe with a 17 in. swing over the bed and 28 in. swing in the gap, but it is also fitted with a capstan head of orthodox pattern, which takes the place of the tailstock. All normal toolroom turning operations are possible on the machine, in addition to the production work which can be carried out with the aid of the capstan, the design thus giving all the major features of two machines in one.

CAPSTAN LATHES

Perhaps the simplest modification for production purposes of the centre lathe is the fitting, in place of the tailstock, of a hand-controlled indexing tool holder, which brings different tools into use successively, so enabling several turning or allied operations to be carried out at one setting. This principle has been known and used on the capstan lathe for many years; the machine is well established, and like the centre lathe it has progressed gradually to the form it now takes. Little change in design can be expected, but modifications to detail take place from time to time. A typical capstan lathe, shown for the first time in its present revised form at the exhibition, is the machine illustrated in Fig. 5. This machine, made by Charles Taylor (Birmingham), Limited, Bartholomew-street, Birmingham, 5, takes stock up to 1¼ in. in diameter or the equivalent in squares and hexagons, and is complete with bar feed. The drive is from a constant horse-power two-speed motor through V-belts to a countershaft and thence by flat belt to the spindle, giving six forward and three reverse speeds. The spindle is controlled by the three foot pedals which are visible in the illustration, and the standard electrical equipment is capable of 12 reversals per minute. Such a machine, simple to set up and operate, is ideal for the rapid and accurate production of turned parts from bar stock.

Basically the same, but available for chucking or bar work, the former to 15½ in. and the latter

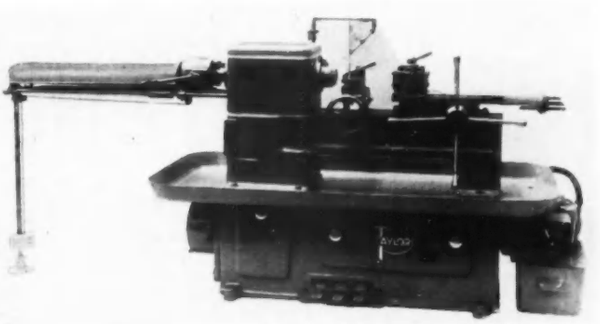
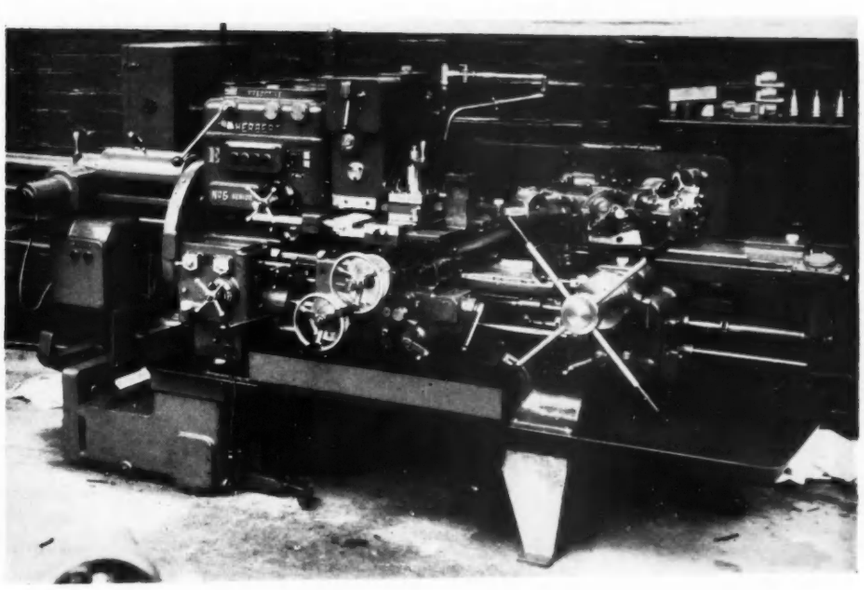


Fig. 5 Capstan lathe taking up to 1¼ in. diameter stock. (Charles Taylor (Birmingham) Ltd.)

Fig. 6 Capstan lathe with pre-selective, 16-speed geared head. (Alfred Herbert, Ltd.)



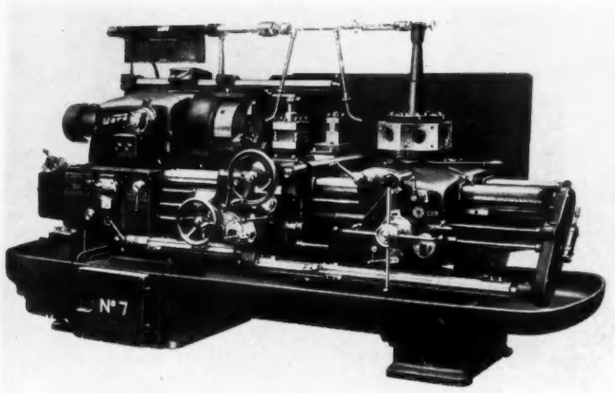


Fig. 7 Chucking turret lathe, 16 in. swing, with pre-selective head and covered ways. (H. W. Ward and Co. Ltd.)

to 2½ in. diameter, and with a very large range of equipment to enable it to carry out any work of which a capstan lathe is capable, is the machine shown in Fig. 6. This is the No. 5 Senior " Preoptive " capstan lathe, made by Alfred Herbert, Limited, Coventry. It is of advanced design, with numerous features for ensuring maximum production, accuracy, durability, and ease of operation. Notable features are the specially designed bed with hardened ways, and the 16 speed power-operated headstock with pre-selective control. The wide speed range covers the extremes of high-speed cutting with tungsten-carbide and the lower speeds necessary for screwing alloy steels.

TURRET LATHES

The turret lathe is so closely related to the capstan that both types of machine are often produced by the same manufacturer. Such is the case with Alfred Herbert, Limited, who had on show examples of their turret lathes, including models with the " Preoptive " headstock.

Typical of modern practice in turret lathe construction is the machine illustrated in Fig. 7. It is the No. 7 " Prelector " lathe made by H. W. Ward and Company, Limited, Selly Oak, Birmingham, 29. This machine, which will take up to 2½ in. diameter bar, or chucked components up to 16 in. swing, has a pre-selective hydraulically operated geared head, giving 12 speeds in forward and reverse over the range 25 to 1,000 r.p.m. It is possible to change not only from one speed to another, but also to effect a simultaneous change of speed and direction of rotation. An interesting feature of this machine, as of several others in the Ward range, is the covered bed, the covers being made of stainless-steel channel sections, fixed to the bed. Cored passages of suitable shape in each saddle allow the movement of these components along the bed.

VERTICAL MACHINES

Technically speaking not lathes, but often so-called, and in any case closely related to the lathe, are the vertical-spindle machines such as that exhibited by Burton, Griffiths and Company, Limited, Mackadown-lane, Kitts Green, Birmingham, 33, and made by Schiess, of Düsseldorf, Germany. This has a maximum turning diameter of 49 in., a range of 16 table speeds with a ratio of 1 to 50, and two ranges of 12 feeds. Speed selection is by a pre-selector handwheel, and as the feed box employs electro-magnetic clutches an electric copying attachment can be fitted if required.

Another machine in the vertical class, which is strictly speaking an automatic machine, but can in some ways be considered as bridging the gap between the fully automatic type and the hand controlled type, is the 24 in. " Vertimax " production lathe exhibited by Charles Churchill and Company, Limited, Coventry-road, South Yardley, Birmingham, 25. It follows the design of the smaller, 18 in. swing " Vertimax " machine, the body of the machine being entirely of fabricated construction. The 24 in. machine will swing work 24 in. in diameter. It has two hydraulically-operated tool slides which can be swivelled from below horizontal to beyond the vertical position, a feature which enables the machine to turn, in addition to normal work, two internal or two external tapers, or one internal and one external taper simultaneously. The machine is designed primarily for repetition work, with the tool slides under fully automatic control, but the setting is so simple that it is possible to use it for short runs of components which would otherwise be made on other machines of the hand-controlled type.

AUTOMATICS

Automatic control of the cycle of operations involved in turning a component is such a well-established practice that the term " automatic " without qualification is generally understood to refer to a machine for carrying out some sort of turning or allied work. The automatic lathe can be divided into several groups; the main types being single-spindle, multi-spindle, sliding head and vertical. Sub-divisions of these groups are possible; for example, on the basis of whether the machines work on bar or on components which require holding in a chuck; but the main constructional groupings still apply. Automatic lathes have developed over the years into highly efficient machines, but the basic designs remain virtually unaltered. As with other machine tools, however, many improvements in detail have been incorporated in the last few years to meet current needs for higher speeds and feeds. The questions of easier setting, safer operation, and the disposal of the larger quantities of swarf produced have also received attention.

Two main types of single-spindle machines were exhibited, the multi-tool and the turret type. Of the former type the American Sundstrand 4A, shown by the Rockwell Machine Tool Company, Limited, and the Churchill Fay 12 in. by 21 in. exhibited by Charles Churchill and Company, Limited, were representative. A close-up of the Churchill machine, showing the tooling, is given in Fig. 8. The machine has hydraulic chucking equipment and hydraulic power starting, and is of very heavy and rigid construction for high cutting speeds. It can be used for work mounted between centres on fixture or arbors, or for chucking work.

Of the turret-type single-spindle machine a good example is afforded by Fig. 9, which illustrates the 68L machine exhibited by B.S.A. Tools, Limited, Mackadown-lane, Kitts Green, Birmingham, 33. This machine is the British version, of equivalent capacity, of the well-known B.S.A. 18L Metric machine. It has a capacity of ¾ in. diameter and the equivalent in square and hexagon, and is provided with a collet mechanism of improved design. A spindle speed range of 53 to 4,480 r.p.m. is provided, and there are 96 cycle times. An important feature of the turret arrangement is the straight withdrawal and advance mechanism, which enables the turret to be retracted rapidly and then advanced to the same position without indexing. This mechanism can be operated as often as desired, and at any point in the machine cycle. It allows deep hole drilling with a single drill. Similar machines are available for chucking work.

To be continued

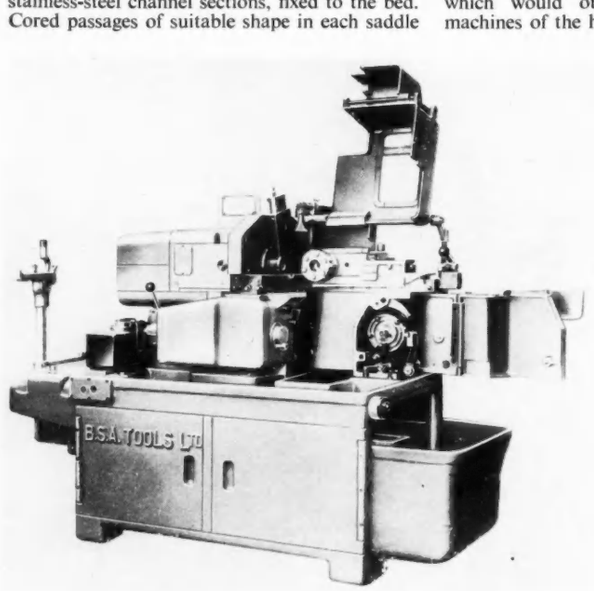


Fig. 9 Single-spindle turret type automatic screw machine of ¾ in. diameter capacity. (B.S.A. Tools, Ltd.)

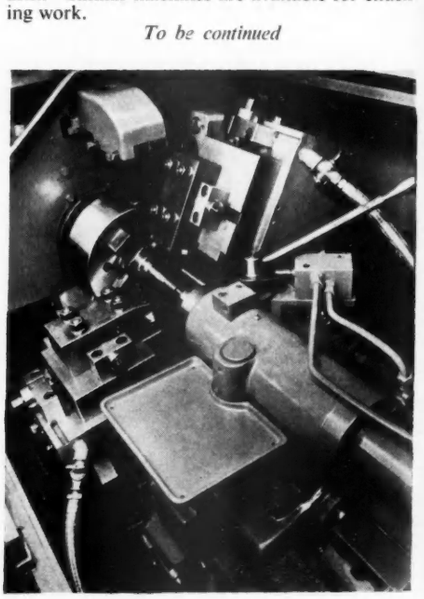


Fig. 8 (Right) Tooling on multi-tool single-spindle automatic lathe. (Charles Churchill and Co. Ltd.)

ATOMIC REVIEW

Conference on reactor physics—droplet suspension in gas as reactor coolant—fluidised uranium-graphite pellets as basis of reactor system—package power reactor—reactor safety experiments—proposal that Britain, the United States and Canada should each specialise in a given reactor type—direct conversion of atomic energy into electric power.

Conference on Reactor Physics

This week the Institute of Physics in collaboration with the British Nuclear Energy Conference held a four-day conference on "The Physics of Nuclear Reactors" at the Institution of Electrical Engineers. Besides representatives of the United Kingdom Atomic Energy Authority and British industry, speakers included notable scientists and engineers from overseas, including Dr. J. R. Dietrich of the Argonne National Laboratory, U.S.A., and Dr. W. B. Lewis of the Chalk River establishment of Atomic Energy of Canada Limited. An exhibition was held concurrently with the conference, which was opened by Sir John Cockcroft on July 3.

The text of the lectures, some of which are reported briefly below, is to be published as a supplement to the *British Journal of Applied Physics*, copies of which will be obtainable from the Institute of Physics, 47 Belgrave-square, London, S.W.1. Reference is also made to the conference on page 5 of this issue.

REACTOR SCIENCES

After opening the conference, Sir John Cockcroft delivered an address entitled "Scientific Problems in the Development of Nuclear Power." These problems, he said, divided conveniently into the physical, chemical and metallurgical aspects. The physicist was concerned with prediction of the nuclear performance of reactors. He had to be able to predict the critical size and the amounts of fuel and the degree of enrichment required to enable it to operate at the designed heat output. He had further to be able to predict the course of the reactivity—how much heat could be extracted per ton of fuel before the fuel had to be changed.

In order to do this he must know a great deal about the interaction of neutrons with the important heavy-element isotopes inducing plutonium 240 and 241. He must know how the number of neutrons per fission changed with neutron energy and the relative chances of a neutron being captured with and without producing fission. He must know the chances of neutrons being absorbed by the fission products formed in the fuel elements, and any non-fissile materials used by the metallurgists and engineers. Different data were required for fast and thermal reactors. The physicist must also keep a watchful eye on the safety of reactors—he must be wary lest changes in temperature or operating conditions induced additional reactivity and caused power increases. He must also study the effects of high-speed high-intensity neutron bombardment on the properties of important structural materials in the reactor, such as graphite and steel.

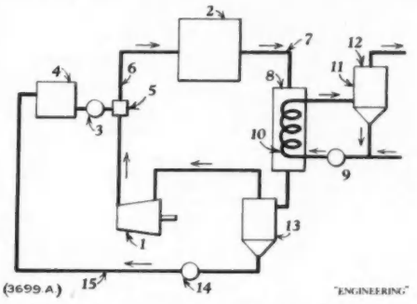
The chemists and metallurgists had the problem of providing all the nuclear materials—fissile and non-fissile—in a high degree of purity. The chemist must devise processes for separation of fertile materials, fissile materials and fission products. The metallurgist had to understand the effect of radiation on uranium and thorium metal at the operating temperature and had to devise methods of counteracting deleterious effects. To do this he had to study the various possible alloys or cermets, bearing in mind the prohibitions of the physicist who disliked neutron absorbing materials and the chemist who disliked processing highly alloyed metals.

The chemists and metallurgists had also to study the compatibility of all the materials used with the coolants specified by the engineer. Thus the reaction of graphite with carbon-dioxide gas at 400 deg. C. in the presence of reactor radiation must be measured; the compatibility of liquid sodium with zirconium and stainless steel at 550 deg. C. must be determined for a reactor of the sodium-graphite type; solutions of uranyl sulphate in water must be compatible with structural materials used in homogeneous reactors. All these problems required prolonged study in test rigs or reactor experiments.

The scientist must also plan ahead, for any new type of reactor was likely to take at least ten years to come into full-scale use from the commencement of work. During this period he had to carry out research and development on any new materials which might be required, such as heavy water, thorium, zirconium and beryllium. Work had to be started many years before full-scale use could be certain. The crystal ball was never more required than in the development of atomic energy.

ADVANCED REACTORS

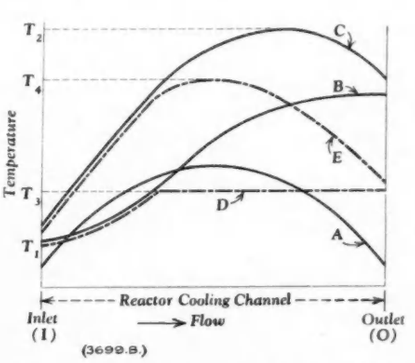
In his lecture "The Physics of Advanced Reactors" Dr. J. R. Dietrich attempted to define the various promising types of solid-fuel power reactors in terms of the neutron-physics



A turbo-pump (1) blows a gas through the reactor (2). A liquid, which can be vaporised under the operating temperature and pressure conditions in the reactor, is delivered by a pump (3) from a reservoir (4) to an injector (5) in the gas pipeline (6) to the reactor; the liquid is carried into the gas stream as a mist or suspension of droplets. In the reactor the mist is vaporised and the vapour in its carrier gas leaves the reactor by a duct (7), through which it flows to a heat exchanger (8).

The secondary circuit, in which steam is raised, comprises a boiler feed pump (9), heat exchanger and water and steam pipes (10) and a separator (11). After separation of water, which returns to the heat exchanger through the pump (9), steam flows through a pipeline (12) to a utilisation system such as a turbine and a condenser. The vapour of the primary fluid is partly condensed in the heat exchanger and conveyed by the carrier gas to a centrifugal separator (13), whence the condensate is transferred by a pump (14) and a pipe (15) back to the reservoir (4) to repeat the process.

Fig. 1 Reactor system for use with a coolant comprising a mist suspension in a carrier gas.



Coolant flows in a fuel channel from the inlet (I) to the outlet (O); curve A represents the heat generated; curve B the temperature rise for a simple gas and C the corresponding temperatures for the fuel elements; while D and E are equivalent curves for the carrier-suspension combination.

Fig. 2 By use of a vaporisable mist suspended in a carrier gas as the reactor coolant, the advantages of heat transfer at constant temperature without the neutron-physics problems associated with a boiling liquid can be achieved.

characteristics of their moderators coolants and fuel cycles. The neutron-physics design objectives which had the greatest effect on power cost were: (i) use of a fertile isotope (uranium 238 or thorium 232) as a major source of energy; (ii) an internal conversion ratio high enough to allow long fuel-element life; (iii) safety characteristics favourable enough to avoid remote location and high containment cost. These objectives were not restrictive enough to define the "best" reactor system, but they were the major factors in determining the composition and geometrical arrangement of specific reactor designs once the type had been chosen. The thermal reactors which were at present being designed or constructed employed uranium 235 as the initial fissile isotope, and there was a strong incentive to utilise ratios of fissile to fertile material which departed as little as possible from the "natural" value. With this additional design qualification, the lattice characteristics appropriate to the various moderator-coolant combinations were still more sharply defined. The characteristics of fast reactors fitted into a quite different pattern. The possible conversion ratio was high on either fuel cycle, and the reactivity changes associated with fuel burn-up were relatively low simply because of the very large fissile-material content of the reactor. The requirement that the average neutron energy be kept high was a rather restrictive one. It appeared now that the range of variation in fast-reactor design would be less than that in the thermal reactor field.

INSTRUMENTATION

Mr. W. Macrae of C. A. Parsons and Company, Limited, delivered a paper on "The Instrumentation of Reactors," in which he observed that most reactor instrumentation was concerned with the measurement and control of the core power output and its effect on the temperature of the reactor components and coolant (if any). There were two main groups of instruments: those operated from detectors sensitive to neutron flux—flux measuring instruments—and those concerned with physical measurements such as temperature and coolant mass flow. In power reactors, instruments were also necessary for the detection of faults in protective fuel containers. Mr. Macrae discussed the principles of various instruments and their relative importance under different operating conditions and concluded with an assessment of the instrument requirements for a large power reactor.

In a paper entitled "The Canadian Research Reactors and their Uses," Dr. W. B. Lewis noted that the heart of the programme at Chalk River was the high-flux heavy-water-moderated NRX reactor. The primary aim justifying this and the even more costly NRU reactor was to explore the possibilities of deriving low-cost electricity from nuclear energy. This aim was not, however, pursued narrowly and the reactors were used to foster basic research in nuclear physics, nuclear chemistry, radiation physics, chemistry and biology. Since separated fissile materials had high intrinsic value in atomic energy research, emphasis had been given to the production of plutonium and uranium 233 and to certain radioisotopes, tritium and cobalt among others. Nuclear power would become important within Canada only if it were cheaper than power from the present-day alternatives. The more costly of these were coal in Ontario, coal and oil in the Maritime Provinces, and oil in remote industrial installations such as mines and wood-pulp mills. Coal in Ontario, at 8 dols. a ton and contributing 3 mills per kWh to the cost of electricity, set the major target. Results obtained in the NRX reactor indicated that once the large development costs had been worked off, nuclear power costs would be definitely lower than this target. Canada was relatively rich in uranium and must immediately consider the particular requirements of both foreign and domestic consumers. Consequently the research was broad and very full programmes lay ahead, not only for the NRX reactor, but also for ZEEP which was mostly used for measurements on fuel arrangements, and a

proposed PTR (Swimming-Pool Test Reactor) which would take over the function of ZEEP for measuring reactivity effects of materials, particularly after irradiation. The most powerful and versatile research reactor was, however, the NRU, a heavy-water-cooled and moderated high flux reactor, which should be in operation this year.

A number of conference papers dealt with reactor materials and we hope to report some of these in a subsequent " Atomic Review."

Reactor Systems

When a gas or liquid is used as a reactor coolant, it takes up heat as sensible heat over a considerable range of temperatures. This necessarily involves some inefficiency. What is more, the reactor has to be designed as a whole to operate at the upper temperature limit of the coolant, although the heat transfer is largely effected at lower coolant temperatures. Admittedly, by extensive use of heat exchangers, the temperature rise within the reactor could be limited to a small value, but in that case pumping losses would be excessive. Cooling at a substantially constant temperature might also theoretically be achieved by evaporating a mass of liquid at boiling point inside the reactor, but the ebullition and bubble formation would introduce an undesirable local variation in the density of the fluid so that uniform nuclear-physical conditions could not conveniently be maintained. To overcome these difficulties a coolant system has been proposed in which cooling is effected by vaporisation of a liquid flowing through the reactor as a mist or suspension of liquid droplets in a carrier vapour or gas. In this way, heat is taken up at a substantially constant temperature by a fluid having the characteristics of a gas of very large specific heat and can be rejected in a condenser at a lower temperature. The liquid is chosen to have a boiling point appropriate to the operating temperature of the reactor, which is usually determined by the thermal limitations of the reactor materials. Since the liquid is present in only small quantities, a higher neutron-capture cross-section can be tolerated than in an equivalent liquid-cooled system or, alternatively, a smaller neutron loss occurs for a given liquid.

SUSPENSION-VAPOUR COMBINATIONS

In addition, the carrier vapour can be chosen with somewhat greater freedom than in a gas-cooled reactor. Possible carrier and suspension arrangements are: light or heavy water in air, sodium, potassium or sodium-potassium alloy in helium (high-temperature slow-fission reactors), and also mists of liquids in their own vapour, such as wet steam. A typical layout is illustrated in Fig. 1. Fig. 2, which compares temperature gradients through reactors employing simple gas cooling and those using the coolants described, shows the temperature and rate of energy release along a reactor cooling channel containing a string of heat-generating fuel elements with coolant flowing in the direction left to right along the abscissa from the inlet (I) to the outlet (O). The heat generated displays an approximately sinusoidal variation along the string, as represented by curve A, while the neutron flux density and hence the rate of fission and the heat generated is greatest at the central region of the string. Curve B represents the temperature rise of a simple gas, such as air or helium, flowing through the cooling channel with an initial temperature T_1; in this case the fuel elements will attain temperatures, as shown by curve C, rising from the inlet end to a maximum value T_2 near the outlet end. The case of the carrier-suspension combination is illustrated by curve D, which shows the temperature of the fluid rising to the boiling point T_3 and thereafter remaining substantially constant; the corresponding temperatures of the fuel elements are represented by curve E. The use of a liquid coolant in a gaseous carrier limits the peak temperature of the fuel to a value T_4, lower than T_2 obtained with a gas coolant. This permits a higher safe power level and a saving in pumping power. (Franz Eugen Simon. Pat. Spec. 735,851.)

It is reported that the United States Atomic Energy Commission is considering the use of a ninth reactor system, employing a fluidised uranium slurry; their eighth approach, the gas-cooled reactor, was mentioned in " Atomic Review " last week. In the latest system, graphite pellets of micron size coated with uranium would be circulated through the reactor core. The project is said to be under examination at the Rice Institute.

Reactor Projects

Fig. 3 shows welders putting the finishing touches to the steel vapour shell of the APPR (Army Package Power Reactor), which Alco Products, Incorporated, are building at Fort Belvoir, Virginia, U.S.A., for the Atomic Energy Commission. It is expected to come into operation early in 1957. The vapour container is 64 ft. high and 36 ft. in diameter, with walls of 7 to 8 in. steel plate to be reinforced with 2 ft. of concrete and is intended to withstand the maximum pressure that might arise should an incident occur. APPR is a 2 MW pressurised-water reactor designed so that components may be carried by air to anywhere in the world and re-assembled to form a self-contained power source. The Fort Belvoir installation will be used to train military personnel, and the Stone and Webster Engineering Corporation of Boston are the engineering contractors. Package atomic power is also being studied as a means of providing power for heating, lighting and air conditioning in a Washington hotel.

Fig. 3 Vapour-containing sphere at Fort Belvoir, U.S.A., for APPR (Army Package Power Reactor), which is nearing completion. The reactor is to be a 2 MW pressurised-water unit, components of which can be carried by air and reassembled to form a self-contained source of power.

SAFETY TESTING

In our issue of January 13 (vol. 181, page 36, 1956) we described some American experiments using the reactor Borax I, which demonstrated the inherent safety of water cooled and moderated reactors. Research on the safety of enriched-uranium heterogeneous reactors is being continued by the Phillips Petroleum Company at the National Reactor Testing Station in Idaho with the aid of the reactors SPERT 1, 2 and 3 (Special Power Excursion Reactor Tests). SPERT 1, which is completed, is a non-pressurised water moderated and reflected reactor using enriched fuel, and is to assist in investigating the manner in which transient behaviour is influenced by such parameters as void coefficient and also in determining safe upper operating limits for permissible excess reactivity, minimum shut-down power level and other factors. SPERT 2 will be a low-pressure (300 lb. per sq. in.) low-temperature (400 deg. F.) reactor for studying the effects of different moderators and reflectors, while SPERT 3 will be a high-pressure (2,500 lb. per sq. in. max.) and high-temperature (670 deg. F.) facility with coolant flows up to 20,000 gal. per min. for performing basic studies of transients in high powered water cooled and moderated reactors.

Sir John Cockcroft has recently stated that Britain will have 16 nuclear power stations by 1965 and that they will supply about one tenth of the country's electrical power. He has also said it is gratifying that Britain, the United States and Canada are specialising on different types of reactor—Britain on gas-cooled, the United States on water-cooled and Canada on heavy-water-cooled systems. If Britain adopted the last named scheme, he said, some 1,000 tons of heavy water would be required each year.

The French Commissariat à l'Énergie Atomique recently announced that operation of the Saclay pile had been stopped owing to a fractured uranium container. There was no danger and once repairs had been carried out operation would be resumed.

Direct Conversion

A process by which, it is claimed, atomic energy can be converted directly into electrical power on a commercial scale, without the use of turbines, generators or other intermediary equipment, has been patented by Dr. R. Rudenberg of Harvard University. The charged particles emitted during nuclear reactions in an atomic pile are channelled by electromagnets into dense streams so enabling electric currents to be induced in secondary coils, as in a transformer. It is understood that alternating current of convenient frequencies can be generated. It should be noted, however, that heat would be generated in the pile as in a normal reactor and unless this were tapped the process would probably be uneconomic. Some laboratory-scale experiments on direct conversion have previously been described (vol. 180, page 419, 1955).

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We are asked to state that, in addition to the 62·5 MVA alternator described on page 508 of our issue of June 15, the Aura station is equipped with two 62·5 MVA and four 37·5 MVA alternators, which were manufactured by the Metropolitan-Vickers Electrical Company, Limited.

In Parliament

ATOMIC ENERGY TERMINOLOGY

Much interest continues to be shown by members of both Houses of Parliament in all matters connected with research and development in the atomic-energy field, as has been borne out by the number of points recently brought forward in questions to Ministers. For example, Mr. Airey Neave (Conservative) drew attention to the need for the introduction of a uniform nomenclature for equipment used in nuclear research and the industrial development of nuclear energy.

He was informed by Mr. R. A. Butler, the Lord Privy Seal, that this need was well recognised. In fact, Mr. Butler said, an expert committee of the British Standards Institution, assisted by the United Kingdom Atomic Energy Authority, was at present engaged on the preparation of a uniform nomenclature covering nuclear science and equipment. The Government were also giving their support to a programme which has been drawn up by the Organisation for European Economic Co-operation for establishing a uniform nomenclature among its member countries. The British Standards glossary of terms would be published in due course, but, in view of the large number of items which had to be covered, it was not possible to say when this would be.

EXPORT OF NUCLEAR REACTORS

Mr. Butler gave Mr. Neave an assurance that the Government were fully alive to the importance of the export of nuclear reactors and components by British industry. The immediate opportunities in this field lay in the export of research reactors, for which some orders had already been secured, but the progress made in the application of nuclear energy to the production of power should put British industry, Mr. Butler considered, in a good position to compete for export business in power reactors. One British firm was at present engaged in the construction of a research reactor in Australia, but the sale of reactors was, naturally, a commercial matter for the manufacturers concerned. On a point raised by Captain G. R. Chetwynd (Labour), as to whether it would be possible to obtain some agreement with the United States by which Britain might supply the machinery and they would supply the fuel required, Mr. Butler said he could only refer to the agreements already reached with that country. He would send Captain Chetwynd copies.

REACTOR SALES TO GERMANY

Inquiries about the sale of atomic reactors to the Federal Republic of Germany were made by Sir James Hutchison, Bt. (Conservative). He desired to know what contracts had been concluded with that country for the sale of reactors and what their size would be; where such reactors were to be manufactured; and the nature of any fissile material to be supplied for such reactors and from what source it would come.

In reply, Mr. Butler said that a provisional order had been placed with a British firm for a small research reactor of the swimming-pool type by one of the German Lander, but this was subject to an agreement being reached between the British Government, the Federal Republic of Germany, and the United Kingdom Atomic Energy Authority covering the supply of fissile material and the reprocessing of spent fuel elements. Discussions were proceeding and, if the agreement was concluded and the order confirmed, the reactor would be manufactured by the firm concerned and the fissile material, in the form of manufactured fuel elements, would be supplied by the Atomic Energy Authority. The material would be uranium enriched in the isotope U235 up to a maximum of 20 per cent. U235. If agreement was reached and the order went through, the enriched fuel would be supplied by the Authority, but, in spite of pressure by Mr. R. R. Stokes (Labour), the Minister declined to say whether this material would, or would not, originate in Britain or the United States.

ATOMIC ENERGY AUTHORITY'S REPORT

It was expected, Mr. Butler said, that the annual report of the Atomic Energy Authority for 1955-56 would be laid before Parliament towards the end of this month. As to a suggestion that that time, just before the summer recess, was not the most suitable for arranging a debate in the House, Mr. Butler reminded Mr. Neave that the first report was published in November, 1955, which had been found to be an inconvenient date. A great effort had been made, therefore, to speed up the forthcoming report to July and he could not undertake that it would be possible to produce the next report earlier than July, but the point would be borne in mind.

Prices Eating into Wages

Mr. Frank Allaun (Labour) raised the problem of dealing with the rising cost of living. He asked that recent Government measures, such as cuts in the bread and milk subsidy, the imposition of purchase tax on necessities, charges on the health service and the removal of housing subsidies, should be reconsidered before requests were made to trade unionists to forgo further wage claims. He suggested that there was a growing feeling among trade unionists that the Government, being unable to cut wages directly, owing to the strength of the unions, were securing that result indirectly by deliberately raising rents, food and other prices.

Sir Anthony Eden, the Prime Minister, to whom the matter was directed, said that there could be no question of reversing the Government's decisions. He thought that Mr. Allaun and, indeed, the whole House, were aware that the Government was striving to steady prices for the future. That was the best way of sustaining the value of wages. It was arguable to what extent subsidies formed a good permanent part of the national economy. Mr. John Hall (Conservative) pointed out that, whereas wages used to chase inflation, the curious position now obtained of inflation chasing after wages.

Efforts of Private Industry

Sir Anthony told Mr. Ernest Davies (Labour) that a statement had been issued regarding his discussions with the chairmen of the Executives of the nationalised industries, respecting the stabilisation of their charges, and that he considered that that statement expressed all that there was to be said upon the subject. Mr. Herbert Morrison (Labour) said that, within proper limits, the Labour Party welcomed the decisions of the nationalised industries. He then inquired what was being done by private industry about limiting prices. Sir Anthony replied that some steps had been taken by private industry at an earlier stage. The statement which had been issued had announced the Government's intentions of continuing to maintain contact with the Trades Union Congress and with employers' representatives in the private sector of industry.

A number of other aspects were raised, in reply to which Sir Anthony said that the discussions which had taken place were being continued and that he had made it clear with whom they were continuing. A point raised by Mr. Hugh Gaitskell (Labour) had really amounted to which should come first, price stabilisation among the nationalised industries or in the private sector of industry. Hitherto, the private sector had been able to complain that the prices of its raw materials were uncertain and there it had a factor to deal with. It was the Government's objective to obtain stability over the whole field. As to the decision of the North Thames Gas Board to maintain the price of gas at its present level for at least two-and-a-half years, this was subject to certain provisos. One of these was that there should not be any major increases in the cost of labour or raw materials. Sir Anthony considered that that was, in itself, a pretty wide reservation.

B.O.A.C. Aircraft Needs

Mr. Harold Watkinson, the Minister of Transport and Civil Aviation, told Air Commodore A. V. Harvey (Conservative) that the Corporation had sent a technical mission to the United States. Many of its competitors were placing orders for large American jet aircraft and the Corporation considered it only prudent to find out all it could about these machines.

B.M.C. Discharges

In a statement on the discharge of 6,000 of its employees by the British Motor Corporation, Mr. Iain Macleod, the Minister of Labour, agreed that the amount of notice given had been profoundly disturbing and said that the load thus suddenly put upon the employment exchanges made it extremely difficult for them to deal with the situation.

He said that the exchanges would try to place as many as possible of the men affected in new jobs near to their homes, but that it would not be possible for all of them to obtain work in their own localities. Through the normal interchange arrangements, details of suitable vacancies in other parts of the Midland region and elsewhere in the country would be made available at the exchanges at which the men concerned would be registering. Among the opportunities for employment in the Midlands were a considerable number in the transport and coal-mining industries. Mr. Macleod said that, apart from about 300 skilled men, all the employees to be discharged were either semi-skilled or unskilled. In the Birmingham area, there were more than 6,000 vacancies; within a reasonable daily travelling distance of Birmingham, 12,600; and, in the Midland region as a whole, about 26,750.

No Technology Degree

In reply to Mr. H. M. King, Ph.D. (Labour), who wanted the Hives Committee to be recommended to make the new qualification in technology a degree and not a diploma, Sir David Eccles, the Minister of Education, said that this would not be done, as the power to confer degrees had become the distinguishing mark of universities. When Dr. King suggested that it should be pointed out to the Minister's advisers "who would object if their own professional qualifications were called Dip.Arts, Dipl.Sc., M.Dip., and Dip.D.," that the granting of degrees would not only be good for euphony but also for the parity of esteem in the battle for advanced technical education, Sir David said that, although everyone desired parity, that was not quite the same thing as saying that everyone should have an exact equality in names.

No Automation Minister

Mr. Maurice Edelman (Labour) urged the Prime Minister to extend the scope of the Ministry of Labour and National Service to include matters affecting automation and to retitle the Ministry accordingly. He felt that the "great crisis" in the motor industry, which automation was likely to increase rather than diminish, rendered it desirable that overall responsibility for matters concerning automation, social, industrial and technical, should be brought under one Minister, rather than remaining "fragmented through a whole variety of Ministers" as at present. Sir Anthony replied that the Minister of Labour was already responsible for the effects of automation, as well as other forms of industrial development, on employment. He did not consider that it would be helpful to make one Minister responsible for all aspects of automation, but he had made arrangements for co-ordination between the Government Departments most concerned. He would be opposed to adding the word "automation" to the title of the Minister of Labour and National Service, which was long enough, and he could not agree that automation was creating the crisis in the motor industry. Most people would probably agree that the difficulty was competition in export markets.

THE HUMAN ELEMENT

Bishop condemns inhumanity of motor-industry sackings—Unions and employers clash over 40 hour week and increased holiday pay—Local strikes in steel industry to be automatically recognised in certain cases—Non-Communist president of A.E.U. faces tactical problems—British Productivity Council urges wider use of work study—Miners may undermine plan to peg coal prices.

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Human Beings on the Scrapheap

The problem raised by the action of Sir Leonard Lord in dismissing 6,000 B.M.C. workers last week, and Mr. Alick Dick's decision not to discuss further a plan to reduce redundancy by increasing short-time working are discussed under Plain Words in this issue. The manner of the dismissals has earned Sir Leonard a sharp rebuke from the Minister of Labour. Now the Church has joined issue with the employers: the Bishop of Coventry, the Right Rev. Cuthbert Bardsley, said last Saturday: " Industry is not a regimented army where the reason for existence is to make money. If there is no longer any work for these men, they cannot just be thrown on the scrapheap of unemployment without care or concern. If that is done these men have a right to be resentful. There must be planning, foresight, love and careful preparation."

Bishop Bardsley has expressed quite simply the feeling of a growing number of responsible persons. Mr. Norman Crump, the City editor of the *Sunday Times*, echoed his words " . . . in principle a shift of labour from the motor industry to coal mining is just what we want. Yet human beings are not chess-men to be moved about the board at will." They have family roots, they belong to a unit of society, they find their security in habits and routines. Mobility of labour are fine words, and something desirable in a dynamic industrial state. But to achieve it needs thought, understanding and care.

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Engineering and Shipbuilding Employers Get Tough

Claims for a reduction of the working week from 44 hours to 40 and for increased holiday pay which were put forward by the Confederation of Shipbuilding and Engineering unions were rejected outright last week by the employers' federation. The employers went even further: they announced that they would reject any general wage claim the unions might be contemplating. The president of the federation, Mr. F. C. Braby, said that the employers were not opposed to increased earnings but that this must come from increased productivity. The industry could not afford any more increases in production costs. They claimed that wage increases throughout the industry during the past 18 months had put up their costs by 12 to 14 per cent. Mr. Braby pointed out that over much of the industry there is already a price " freeze," imposed by foreign competition and consumer resistance. In his view this was much more effective then exhortations or gentlemen's agreements not to raise prices. Costs must be kept stable, or the industry will have to face a major crisis.

The unions' reactions to the rejection of their claims, and to the warning about making any general wage claim, do not suggest that there is much chance of industrial peace in the industry. The unions have been pointing out for some time that the efficient companies do not find it difficult to pay higher wages and that they are the most successful in export markets. A striking example of this in the motor industry is the success of Ford and Vauxhall, whose wage levels are certainly no lower than B.M.C's. It is also fairly clear that new techniques and automatic machinery require high wage levels to make them worth while.

The real question at issue is one of living standards, of which leisure is a vital component. If Britain is to remain a great industrial power her industry must modernise and must have good relations between employees and employers. Only more, and more efficient, production backed by first-class marketing, can keep back inflation and increase exports. The unions must concern themselves with efficiency at least as much as with working hours, holidays and wage levels.

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Steel Situation Deteriorates

Nature abhors a vacuum just as much in industrial relations as it does in physics. Usually in human relations the vacuum is filled in a way which leaves much to be desired and such is very much the case in steel. Local strikes in the steel industry, which have arisen in instances where managements have used staff to break the overtime ban by maintenance men, have become official.

Future strikes which may arise will now become automatically recognised. The best that can apparently be done in this situation is for informal talks to be resumed between employers and union representatives in the middle of this week. The situation is exceedingly confused. Not all steel works are affected to the same extent. Generally strip and sheet are badly hit but there is much less sympathy for the strike at certain tube mills and their integrated steel mills.

One of the worst aspects of the problem is that the steel industry is in the throes of a confusing dispute behind which lies an important matter of principle (namely, differentials for skill) at a time when labour-management relations in general are becoming increasingly strained. Tempers are rising in many engineering unions and the T.G.W.U. is in a similar state. In the past, the steel workers have been an island of tranquillity in the stormy seas of union-management relations. This is not so to-day. There are signs that the ferment in labour troubles is going to build up to a peak just after the round of autumn trade-union conferences.

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A.E.U. Votes for Carron

The bid by the Communist element in the A.E.U. to take the presidency has failed. Mr. W. J. Carron, a native of Hull, was voted in on the second ballot by a substantial majority, although the Communist candidate easily led the poll on the first vote. So far as it goes this is an important victory for moderation and for the right wing of the trade-union movement. Mr. Carron is, however, likely to have plenty of problems on his hands from the start.

The first one is that his own election touches off a series of vacancies which have to be filled and these could be a means of strengthening Communist influence on the executive. In standing for the presidency Mr. Carron has forfeited his seat as the representative of the Eastern Region on the executive and the vacancy may be filled by a Communist from Sheffield. If this should occur, the Communists would have a majority of one on the national executive as the president and the secretary do not usually vote. The secretaryship is also to be filled shortly and the candidates in this case are a London Communist and a Scots moderate.

One way and another, therefore, Mr. Carron has a spirited team to handle. It is not only that he is likely to have to face a form of conspiracy at the top among the Communist element but also that he is likely to wish to strengthen the power of the national executive which has not been fostered to a notable extent by Mr. Openshaw, the retiring president. Meanwhile, Mr. Carron will have to act as general secretary as well as president until the election takes place. This summer is going to be a test indeed for a new type of Carron iron.

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Why Not Work Study ?

This is the title of a pamphlet published last week by the British Productivity Council (*BPC Action Pamphlet* 7, 9*d.*), under the signatures of its chairman, Mr. J. Crawford (General President of the National Union of Boot and Shoe operatives) and its vice-chairman, Mr. McCorquodale (a vice-president of the British Employers' Federation).

This is a powerful call for a wider use of the technique of work study, which is generally acknowledged in British industry to lead " in practice to lower costs, higher earnings, quicker output, less waste and better use of materials and plant." The British Productivity Council believe that it is one of the most efficient means of raising productivity and has devoted a major proportion of its attention and resources to promoting its wider adoption. The pamphlet summarises " for the uninitiated " what work study is—a compound of work measurement and method study—how it is applied, and how snags sometimes associated with its introduction can be avoided. Appendices deal briefly with the available literature (a great deal is omitted), instructional films, training facilities and the work of the BPC work study unit.

It is indeed surprising that so little time and attention should be paid to such techniques and so much to price stability, wage restraint, redundancy and the like. In the words of Sir Ewart Smith (a deputy chairman of I.C.I.) British industry has as yet scarcely " scratched the surface " of the potential improvements in efficiency which the whole-scale use of work study can confirm. Here, surely, is something for the unions as well as for the employers—for efficiency makes possible higher earnings as well as higher profits.

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Miners in Conference

The coal miners have begun their annual conference at Ramsgate this week and there is plenty on the agenda to freeze the good intentions of the National Coal Board. The Coal Board said last week in freezing coal prices for the next 12 months that they would stay fixed provided nothing quite unexpected or exceptional was to turn up. Any Coal Board official who wishes to encounter the " exceptional " might consider a trip to Ramsgate.

Area conferences held earlier this year have made it quite clear that the miners expect a new wage claim to be put forward this autumn. Both Scotland and South Wales have come out strongly in favour of an increase. There are two resolutions on the agenda about wages and each calls for a large claim. Even if the executive is successful by means of such well-worn techniques as composite resolutions, referring back and the like in soft-pedalling a big wage demand—or at least taking the sting out of it by getting the timing of the claim into their own hands—there are other issues to be debated which could put pressure on coal from the side of costs. A shorter working week, higher pay for special shifts and larger contributions by the board to the miners' pension scheme are all down for discussion and it may be that in avoiding the question of wages the executive may be forced to bring these other matters into relief.

So far as the price pegging is concerned, the N.C.B. has a slight advantage since coal prices were raised on June 1. Nevertheless it could be seriously embarrassing if it had to give way to a substantial increase in costs from the side of wages, whether it took the form of larger pay or shorter hours. Growing pressure on deflation and price pegging (serious contingencies apart) till the middle of next year may give the N.C.B. added backbone in dealing with the unions. At the moment, there is certainly little sound of wage restraint in the air at Ramsgate.

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